For Katelijne, Elias, Quinten en Tristan

Ghent University
Faculty of Arts and Philosophy
Department of Art, Music and Theatre Studies

The Music Paint Machine

An embodied constructivist approach to technology-enhanced instrumental music instruction

---

Luc Nijs

Thesis submitted to fulfill the requirements for the degree of
Doctor in Art Sciences
Academic year 2012-2013
Promotor: Marc Leman

De “Music Paint Machine”. Een lichamelijk constructivistiche benadering van het instrumentaal muziekonderwijs.

I certify that this thesis, and the research to which it refers, are the product of my own work, and that any ideas or quotations from the work of other people, published or otherwise, are fully acknowledged in accordance with the standard referencing practices of the discipline. Copyright material has been included under the guidelines of academic fair us. This thesis is published for non-educational purposes.

This research was supported by the Methusalem Funding of the Flemish Government.

ISBN: 978-90-7083-094-6

Ghent University
Faculty of Arts and Philosophy
Department of Art, Music and Theatre Studies

Promotor:	Prof. Dr. Marc Leman
Reading committee:	Prof. Dr. Anna-Rita Addessi Prof. Dr. Dirk Moelants Prof. Dr. André Mottart Dr. Micheline Lesaffre Dr. Peter Van Poucke
Examination committee:	Prof. Dr. Jean Bourgeois (chair) Prof. Dr. Marc Leman Prof. Dr. Anna-Rita Addessi Prof. Dr. Dirk Moelants Prof. Dr. André Mottart Dr. Micheline Lesaffre Dr. Peter Van Poucke Prof. Dr. Francis Maes Prof. Dr. Christel Stalpaerts Prof. Dr. Ir. Leon Van Noorden

Ghent University
Faculty of Arts and Philosophy

Department of Art, Music and Theatre Studies
IPEM - Institute for Psychoacoustics and Electronic Music
Blandijnberg 2, B-9000 Ghent, Belgium
Tel.: +32 (0)9 264 4126 Fax.: +32 (0)9 264 4143

Thesis submitted to fulfill the requirements for the degree of
Doctor in Art Sciences
Academic year 2012-2013

∴

“Don’t only practice your art,
but force your way into its secrets,
for it and knowledge can raise men to the divine.”

Ludwig van Beethoven

Acknowledgements

This work has been a journey, enriched by the presence and contributions of many people.

In the first place I would like to express my profound gratitude to my supervisor, Prof. Dr. Marc Leman, who gave me the opportunity to do my research and always pushed me to the limits of my abilities. His work was, and will continue to be, a source of inspiration. I see it as a challenge and personal goal to bring his important work on embodied music cognition to the field of music education.

It was a pleasure working together with so many colleagues at IPEM, many of who shared their knowledge and experience with me and thereby contributed to my research. I would like to thank Dr. Micheline Lesaffre for the close collaboration, the advice and support. My appreciation also goes to Dr. Leon Van Noorden, for the interesting discussions, and to Dr. Michiel Demey, Dr. Matthias Demoucron, and Dr. Chris Muller for the fine collaboration. Furthermore, I would like to thank Denis Amelynck for helping me out with statistics.

A major part of my research was the development of the Music Paint Machine, which could not have been realized without the help of Dr. P. Coussement, Drs. Bart Moens and Ivan Schepers. The creativity and engagement of Ivan have no limits. It was a real pleasure, both personally and professionally, to have spent together all those moments of brainstorming, preparing stuff and trying out different possibilities and solutions. The same goes for Bart, with whom it was really a great pleasure working together.

My special appreciation also goes to Dr. Pieter-Jan Maes, with whom I shared the desk from day one. The conversations on our research, the small talks on life and the drinks from time to time were a nice part of my days at IPEM.

Thanks also to Aagje Lachaert for the linguistic and administrative support, to Katrien Debouck for the sandwiches and the administrative support, and to Gitte Callaert for helping with the layout of this thesis.

I would like to thank the members of my guidance committee, the reading and exam committee and the reviewers of my articles for their efforts in reviewing and evaluating my research. Their critical considerations have always contributed to my work.

Furthermore I would like to express my gratitude to the teachers and students that participated in the experiments. Especially Merlijn, Jeanne, Luisa, Mauro, Gabriel, Nora, Bryan, Siel, Manou, Merel, Julie and Achiel and their parents for the fine and engaging participation in my research. It is wonderful to know that they continue to be my students, hopefully for many years to come.

Special thanks go to Dr. Luiz Naveda, for being my friend, for the listening ear and the supportive talks and to Dr. Frank Desmet, for the fine discussions and the friendship.

Thanks also to Peter, Heleen and Peter for lending me their house, where I could work and write in isolation.

Special thanks to my dearest mother for always being ready to help Katelijne and me when necessary, and for always being there for my children.

And finally, my deepest gratitude goes to my wife, Katelijne, for her unconditional love and support, her patience and compassion, and to my sons, Elias, Quinten and Tristan, for their love and hugs, the patience and enthusiasm, and for reminding me daily that there is more to life than a PhD.

Luc Nijs
Ghent, September 2012

Table of Contents

List of acronyms

CEQ	Classroom Experience Questionnaire
HME	Home Musical Environment
IMMA	Intermediary Measures of Music Audiation
M-ABC2	Movement Assessment Battery for Children 2
PCK	Pedagogical Content Knowledge
PLE	Powerful Learning Environment
PMMA	Primary Measures of Music Audiation
SSRS	Schwarzer Self-regulation Scale
ZPD	Zone of proximal development

Nederlandse samenvatting

Sinds mensenheugenis is muziek een onderdeel van het dagdagelijks leven van heel wat mensen. Sommigen vinden voldoening in het luisteren naar muziek, anderen gaan op zoek naar een meer actieve vorm van muziekbeleving. Een manier bij uitstek om muziek actief te beleven is het bespelen van een (traditioneel) muziekinstrument. Het laat mensen toe om zichzelf uit te drukken via eigen muzikale creaties of via muziek die door anderen werd gecomponeerd. Maar het leren bespelen van een muziekinstrument gaat vaak gepaard met een lang en intensief leerproces. Het vergt daarom heel wat motivatie, doorzettingsvermogen en zelfs zelfdiscipline.

Computer technologie is ook een vast onderdeel geworden van het dagdagelijks leven van een steeds grotere groep mensen. En de wijze waarop we met computers omgaan, verandert voortdurend op basis van nieuwe technologische ontwikkelingen. We drukken niet langer op knopjes maar controleren computers met de stem en met beweging. We doen alles ook steeds meer draadloos. En dat verandert heel wat aspecten van ons dagelijks leven.

Net zoals technologie ons dagelijks functioneren beïnvloedt, zo heeft het ook een impact op muziekbeleving en op muziekonderwijs. Technologische ontwikkelingen bieden nieuwe mogelijkheden om muziek te beluisteren en om zelf muziek te maken. We kunnen immers overal naar muziek luisteren, we maken online speellijsten, delen die met anderen en we vinden muziek terug via allerlei nieuwe omgangsvormen met de computer (bvb. door een melodie te neuriën of door het karakter van de muziek lichamelijk uit te beelden). Verder worden er nieuwe manieren gevonden om zelf muziek te maken. Allerhande soft- en hardware maken het mogelijk om op een eenvoudige wijze muziek te componeren en uit te voeren. Deze kunnen de traditionele instrumenten vervangen (bvb. Denis & Jouvelot, 2005). Waarom nog fagot, cello of viool leren spelen als je muziek kan maken met de Wii® of Kinect®? De inzet die nodig is om een traditioneel muziekinstrument onder de knie te krijgen staat immers in schril contrast met de plug en play technologie van vandaag. Of ze kunnen gecombineerd worden. En dat betekent ook dat een beroep kan gedaan worden op technologie om een traditioneel instrument te leren bespelen. Volgens sommigen zelfs in die mate dat de technologie een leraar kan vervangen.

In deze thesis worden twee werelden bij elkaar gebracht, namelijk die van het traditionele muziekinstrument en die van de technologie. Dat gebeurt via een interactief muzieksysteem, genaamd de "Music Paint Machine", dat ontworpen is ter ondersteuning en ter verrijking van het instrumentaal muziekonderwijs. Het systeem laat een muzikant toe om een digitale tekening of schilderij te creëren door het musiceren met een (traditioneel) muziekinstrument te combineren met diverse lichaamsbewegingen. Eigenschappen van de muziek (bvb toonhoogte, geluidssterkte) en bepaalde bewegingen (bvb. draaien, buigen) worden omgezet in eigenschappen van de tekening (bvb. verticale positie op het digitale tekenblad, dikte van een lijn of punt).

Het onderzoek dat geleid heeft tot de realisatie van dit systeem is gekaderd binnen het onderzoeksparadigma van de belichaamde muziekcognitie (Leman, 2007). De theorie van de belichaamde muziekcognitie stelt dat het cognitief verwerken van muziek gebaseerd is op lijfelijkheid. Muziek begrijpen en begrijpbaar maken zou te maken hebben met hoe muziek vertaald wordt naar of omgezet wordt in lichamelijke ervaringen. Binnen dit onderzoeksparadigma wordt daarom, op basis van nieuwe technologische ontwikkelingen, bestudeerd hoe lichaam en muziek zich tot elkaar verhouden. Interactieve muzieksystemen die bewegingssensoren gebruiken laten toe om de lichamelijke aspecten van muziekbeleving op kwantitatieve wijze te bestuderen en dit op een manier die de muzikale beleving niet stoort (zoals bvb in een experimentele setting) maar juist stimuleert. Steeds vaker wordt geopperd dat dergelijke systemen ook een educatieve meerwaarde kunnen hebben. Ze laten toe om het verondersteld multimodale karakter van muziekbeleving te benutten en om lichaamsbeweging te gebruiken in functie van de ontwikkeling van muzikale vaardigheden. Het is dan ook niet verwonderlijk dat heel wat onderzoek zich toespits op deze educatieve meerwaarde en probeert na te gaan welk soort systemen ontworpen kunnen worden ter bevordering van de muzikale ontwikkeling.

Het is binnen die specifieke context, namelijk het muziektechnologisch educatief onderzoek, dat deze thesis kadert.

De onderzoeksvraag van het gevoerde onderzoek luidt als volgt:

Hoe en in welke mate kan een interactief muzieksysteem bijdragen tot de ontwikkeling van een lijfelijk begrip van muziek, wanneer we een muziekinstrument leren bespelen?

Het aanpakken van deze onderzoeksvraag heeft geleid tot drie luiken: een pedagogisch, een technologisch en een empirisch luik.

In het eerste luik (Deel 1) wordt een pedagogisch-didactisch kader ontwikkeld. Eerst worden de verschillende componenten van de instrumentale muziekles besproken (Hoofdstuk 1). Deze componenten zijn de leerling, de leraar, de interactie tussen beiden en het muzikale materiaal dat wordt aangeboden en gebruikt (Kennel, 2002). Vervolgens wordt vertrokken van een aantal karakteristieken die in de muziekeducatieve en musicologische literatuur wel eens vaker aan het traditionele instrumentaal muziekonderwijs worden toegeschreven en die regelmatig worden bekritiseerd (Hoofdstuk 2). Deze karakteristieken zijn een schools leerling-meester regime, de overheersende rol van de partituur en een vervreemding van de leefwereld van de leerlingen. Er wordt nagegaan hoe deze verschillende karakteristieken de verschillende componenten van de muziekles kunnen beïnvloeden. Tot slot van het pedagogisch-didactisch luik worden het constructivisme en de theorie van de belichaamde muziekcognitie gecombineerd om een alternatieve benadering voor het traditionalistisch instrumentaal muziekonderwijs te formuleren. Hierbij wordt de nadruk gelegd op de centrale en autonome rol van de leerling, op de noodzaak om kennis op te bouwen vanuit de eigen ervaring, op het belang van exploreren en experimenteren en op de rol van het lichaam in het ontwikkelen van muzikale vaardigheden.

In het tweede luik van deze thesis (Deel 2) wordt een technologisch kader ontwikkeld. Eerst geven we een overzicht van bestaande interactieve muzieksystemen die het leren bespelen van een instrument willen ondersteunen (Hoofdstuk 4, paragraaf 4.1). Dit overzicht geeft aan dat heel wat interessante systemen worden ontwikkeld waarin visuele feedback een prominente rol speelt. Die visuele feedback wordt gebruikt om leerlingen en leraars te informeren over aspecten van het musiceren, zoals toonhoogte of timbre. Maar ook steeds meer systemen integreren bewegingssensoren die het daardoor mogelijk maken om visuele feedback te geven over lichamelijke aspecten van het musiceren, zoals een juiste houding.

Vervolgens argumenteren we dat interactieve muzieksystemen door deze twee kenmerken, nl. het gebruiken van lichaamsbeweging en het integreren van visuele feedback, kunnen bijdragen tot een lichamelijk constructivistische benadering van het instrumentaal muziekonderwijs (Hoofdstuk 4: 4.2 en 4.3).

Interactieve systemen worden verondersteld een leeromgeving te creëren waarin de ervaring van de leerling tijdens de interactie met het systeem centraal staat. Op die manier kunnen leerlingen kennis opbouwen vanuit hun persoonlijke ervaring. Visuele feedback kan de constructie van kennis ondersteunen door invloed uit te oefenen op de cognitieve verwerking van nieuwe informatie. Door het effect van een bepaalde handeling visueel voor te stellen, kan de koppeling tussen het perceptuele resultaat en die handeling verduidelijkt worden. Dat kan leiden tot het bijsturen of fijnstellen van de instrumentale techniek of van de muzikale expressie. Het integreren van visuele feedback speelt bovendien in op het multi-zintuiglijke karakter van de muziekbeleving. Er wordt echter benadrukt dat visuele feedback ook een negatief effect kan hebben op het leren omdat het eventueel een extra mentale belasting veroorzaakt. De manier waarop de feedback informatie verschaft, bepaalt dus in grote mate de educatieve meerwaarde van het systeem. Bovendien kan er zich een afhankelijkheid van de visuele feedback ontwikkelen wanneer deze veelvuldig wordt verstrekt.

Na het overzicht van verschillende bestaande interactieve muzieksystemen en na de uiteenzetting over de rol die dergelijke systemen kunnen spelen, stellen we het interactief systeem voor dat tijdens dit onderzoek werd ontwikkeld (Hoofdstuk 5). Dit systeem, genaamd “Music Paint Machine”, maakt het mogelijk om een digitale tekening of schilderij te creëren door een muziekinstrument te bespelen en door specifieke bewegingen te maken tijdens het spelen. Dit systeem is, net als zovele andere systemen, gebaseerd op het monitoren van geluid en beweging. Toch zijn wij er van overtuigd dat het systeem zich op een aantal manieren onderscheidt van de meeste bestaande interactieve muzieksystemen. Vooreerst omdat het verder gaat dan het louter verstrekken van informatie. Veeleer wordt de combinatie van muziek, beweging en visualisatie gebruikt om leerlingen uit te nodigen tot exploreren en experimenteren met muziek, muziekinstrument, beweging en visuele representaties. De nadruk ligt niet langer op een cognitieve controle van het musiceren op basis van symbolische representaties, maar op het fysiek, auditief en visueel ervaren van de muziek.

De Music Paint Machine geeft bovendien een actieve rol aan lichaamsbeweging (dus niet louter monitoren). Het systeem wordt gecontroleerd door de combinatie van muziek en beweging. Op die manier hopen we dat het systeem kan inspelen op de lichamelijke processen die ten grondslag liggen aan de wijze waarop we betekenis geven aan muziek. Door het stimuleren van een lichamelijke betrokkenheid bij de muziek kan een lichamelijke vrijheid ontwikkeld worden die toelaat om tijdens het musiceren helemaal op te gaan in de muziek. We menen dat deze visie ondersteund wordt door de inzichten op basis van het principe van *differential learning* (Schöllhorn, 2000) en de *variability of practice hypothesis* (R. A. Schmidt, 1975). Beide pleiten voor meer variabiliteit in het oefenen van een bepaalde techniek als alternatief voor het steeds opnieuw en zo correct mogelijk herhalen van een voorgeschreven houding of beweging. We argumenteren bovendien dat dit bevorderlijk is voor de ontwikkeling van een optimale relatie met het muziekinstrument.

Naast het exploreren en experimenteren, kan de Music Paint Machine ingezet worden om specifieke leerdoelen te ondersteunen. Het systeem is qua configuratie zo flexibel dat de wijze waarop muziek en beweging vertaald worden in een visuele representatie kan aangepast worden aan de specifieke noden van een bepaalde leersituatie. Op die manier kan, via de interactie met het systeem, een bepaalde leerinhoud vertrekken van een zeer concrete ervaring die dient als opstap naar een meer symbolische of abstracte vorm van kennis.

In het derde luik van deze thesis bespreken we dan het empirische gedeelte van het onderzoek. Eerst gaan we in op de onderliggende gedachte van het empirische kader, namelijk dat de mogelijke integratie van de Music Paint Machine in een realistische leersituatie een conditio sine qua non is om te komen tot een relevant en waardevol wetenschappelijk onderzoek (Hoofdstuk 6). Dat heeft geleid tot de drie doelstellingen die de ontwikkeling van het empirisch kader hebben gestuurd. Een eerste doelstelling is het vertrekken vanuit de pedagogie. Niet de technologische hoogstandjes maar de pedagogisch-didactische ideeën en doelstellingen moesten de drijfveer van het onderzoek zijn. Een tweede doelstelling is de verbondenheid met de praktijk. Het onderzoek dient relevant te zijn voor het dagdagelijks instrumentaal muziekonderwijs. Dat houdt in dat de kennis en ervaring van leraars en leerlingen een belangrijke bron van informatie zijn. Een derde doelstelling kreeg vorm doorheen het onderzoek en betreft de focus van het empirisch onderzoek. Gaandeweg werd duidelijk dat het evalueren van de effectiviteit van het systeem niet enkel gebaseerd mag zijn op het testen van leeruitkomsten, maar op de wijze waarop het systeem de verschillende componenten van een instrumentale muziekles (leerling, leraar, interactie, materiaal) beïnvloedt. Een educatieve technologie is niet zoiets als een onafhankelijke variabele die ingevoerd wordt en enkel en alleen door de intrinsieke eigenschappen van het systeem het leerproces al dan niet positief beïnvloedt.

Vooraleer de experimenten met de Music Paint Machine besproken worden, gaan we nog in op een theoretisch onderzoek naar de relatie tussen muzikant en muziekinstrument (Hoofdstuk 7). We argumenteren dat een optimale relatie gekenmerkt wordt door het "inlijven" van het instrument. Met andere woorden, muzikant en muziekinstrument versmelten met elkaar. We ontrafelen de processen die ten grondslag liggen aan dergelijke relatie en komen zo tot het definiëren van de componenten van een lijfelijke interactie ("embodied interaction") met de muziek. Deze componenten zijn: een optimale ervaring, de directe (zonder bewuste cognitieve bemiddeling) perceptie van de omgeving, en een manier van spelen die volledig kan terugvallen op de vaardigheden van de speler. De optimale – of: flow – ervaring, waarin men helemaal opgaat in wat men aan het doen is, wordt gedefineerd als een combinatie van presence en een goed gevoel. Presence is een concept die ontleend werd aan het onderzoek naar het zich aanwezig voelen in een computergegenereerde virtuele realiteit. In deze thesis wordt dit concept uitgewerkt binnen de theorie van de belichaamde muziekcognitie.

Dit theoretisch onderzoek heeft de basis gelegd voor het ontwerp van de Music Paint Machine maar ook voor de experimenten met het systeem.

Het eerste experiment dat we beschrijven, onderzocht de wijze waarop muzikanten de interactie met de Music Paint Machine hebben ervaren (Hoofdstuk 8). Er werd gepeild naar de mate waarin het systeem een optimale ervaring kan stimuleren. Dat gebeurde op basis van twee vragenlijsten: de Flow State Scale (Jackson & Eklund, 2004) en een zelf ontworpen presence vragenlijst. Op die manier hebben we het meten van presence tijdens het musiceren met een interactief muzieksysteem geïntroduceerd in het muziekonderzoek. Verder werd er nagegaan hoe de deelnemers aan het experiment de educatieve relevantie van de Music Paint Machine inschatten. De resultaten van de vragenlijsten over de subjectieve ervaring (flow en presence) suggereren dat het systeem een optimale ervaring kan teweegbrengen. Met andere woorden, muzikanten gingen vaak helemaal op in het “schilderen” met muziek en beweging. Bovendien bevestigen de resultaten de theoretisch speculatie dat de flow ervaring en de ervaring van presence intrinsiek met elkaar zijn verbonden. In het bijzonder konden we aantonen dat de ervaring van presence bepalend is voor de flow ervaring (Hoofdstuk 9). De resultaten van de vragenlijst over het didactisch potentieel suggereren dat het systeem als relevant wordt ervaren voor het leren bespelen van een instrument en om muziek te leren begrijpen.

Het tweede experiment dat we bespreken is een longitudinale studie waarin kinderen uit het eerste en tweede leerjaar gedurende negen maanden clarineo leerden spelen (Hoofdstuk 10). Wekelijks kregen 6 kinderen (experimentele groep) les met de Music Paint Machine en zes kinderen (controle groep) zonder het systeem. Dat gebeurde in groepjes van drie en telkens gedurende één uur. De leerinhoud die in de lessen behandeld werd, was voor alle groepjes dezelfde. We gingen na of het gebruik van de Music Paint Machine een effect heeft op de ontwikkeling van “music aptitude” (Gordon, 1986). Dit is het aangeboren muzikale potentieel van een kind dat zich tijdens de eerste negen levensjaren kan ontwikkelen op basis op basis van de muzikale ervaringen die het heeft. Volgens Gordon hangt die ontwikkeling ook in grote mate af van de kwaliteit van het muziekonderwijs dat het kind geniet in die eerste cruciale jaren. In de longitudinale studie wordt verondersteld dat een interactief muzieksysteem dat werkt met beweging en visuele feedback kan bijdragen tot die kwaliteit en daardoor ook tot de realisatie van het muzikale potentieel. De resultaten tonen echter geen significant verschil tussen de controle en de experimentele groep. Doorheen de studie werd echter duidelijk dat een andere aanpak nodig is om na te gaan hoe een interactief muzieksysteem het lesgeven kan ondersteunen. De leerprocessen van leerlingen worden door heel wat factoren binnen en buiten de klas bepaald. Wekelijks werd er ervaren hoezeer het gebruiken van een interactief systeem een impact heeft op het klasgebeuren. Het werd ook steeds duidelijker in welke mate een dergelijk systeem in staat is om een transformatie teweeg te brengen in de wijze waarop de leraar en de leerlingen zich tot elkaar verhouden (interactie) en in de wijze waarop de les wordt vormgegeven (didactisch denken en handelen). Het in kaart brengen van deze transformatie dient een onderdeel te zijn van onderzoek dat zich toespitst op het educatief gebruik van interactieve muzieksystemen.

In een laatste deel van deze thesis (deel 4), bespreken we eerst de bijdragen van het onderzoek dat in deze thesis wordt voorgesteld. Daarop volgt een algemene discussie over verschillende aspecten van het onderzoek. We eindigen met een conclusie en vooruitzichten voor verder onderzoek.

English summary

Since time immemorial, music is part of the daily live of many people. Some find satisfaction in listening to music, others look for a more active form of musical involvement. One way to be actively involved in music is playing a (traditional) musical instrument. It allows people to express themselves by creating their own music or by performing music that is composed by others. But learning how to play a musical instrument often implies a long and intensive learning process. It therefore requires a lot of motivation, perseverance and even self-discipline.

Computer technology has also become part of our daily functioning. Moreover, ongoing technological developments (e.g. increasing computational power and expanding context through embedded computing) continuously change the way we interact with computers (Dourish, 2004). The traditional desktop computing is increasingly complemented and possibly even gradually replaced by a new breed of computational systems in which mouse and keyboard are exchanged for body and body movements as controller.

In the same way as technology has changed so many aspects of our daily activities, it has influenced the way we involve in music. New ways of interacting with the computer have introduced new possibilities for listening and playing. Indeed, we can listen to music anywhere, we make online play lists, share them through social networks and we retrieve music through all kinds of new ways of dealing with the computer (e.g. query by humming or by physically expressing the character of the music we look for). Furthermore, a variety of soft- and hardware applications have introduced new ways of composing and making music. These applications can replace the traditional instruments (e.g. Denis & Jouvelot, 2005). Why should one engage in the endeavour of learning how to play the bassoon, the cello or the violin if it is possible to more easily make music with new technologies such as the Wii® or the Kinect®? After all, the effort required for learning how to play traditional musical instruments contrasts sharply with the plug and play devices of today. However, technology can also play a more complementary role and, for example, support learning how to play a musical instrument. Indeed, on the one hand, music educators increasingly solicit these new technological possibilities in order to support music teaching and learning. On the other hand, some people believe that technology can replace the teacher.

In this thesis we combine the world of technology and the world of traditional musical instruments. We have developed an interactive computer system, called the Music Paint Machine, which is controlled by playing music on a (traditional) music instrument while moving on a coloured pressure mat. The system allows a musician to make a digital painting through the combination of sound and movement. Properties of the music (e.g. pitch, amplitude) and certain body movements (e.g. twisting the upper body, moving the feet) are mapped to properties of the painting (e.g. position on the digital drawing board, stroke size, colour). This interactive music system aims at supporting and enriching instrumental music instruction.

The investigations with the Music Paint Machine are framed within the embodied music cognition research paradigm (Leman, 2007). The theory of embodied music cognition asserts that the body mediates the cognitive processing of music. Understanding music and communicating this understanding is believed to rely on the process of translating music into a repertoire of corporeal experiences. Therefore, within the embodied music cognition paradigm, research focuses on the relationship between music, body and technology. Interactive music systems that integrate motion sensors allow the quantitative investigation of the bodily aspects of musical experience in an unobtrusive way. Increasingly, it is suggested that such systems also have an educational value. They appeal to the multimodal nature of musical experience and use body movement or the monitoring of these movements to develop musical skills. Not surprisingly, a growing number of research projects focuses on this educational value, trying to determine what type of systems can be designed to promote musical development.

It is within that specific context, namely music educational technology research, that this thesis is situated.

The presented research was guided by the following research question:

> *How and to what degree can an interactive music system contribute to the development of an embodied understanding of music when learning how to play a musical instrument?*

Addressing this research question has lead to the development of three frameworks: a pedagogical, a technological, and an empirical framework.

In PART 1 of this thesis, the pedagogical framework is developed. First we describe the components of music instruction (Chapter 1). These components are the learner, the teacher, the interaction between the two and the musical material (Kennel, 2002). Next, we describe a number of characteristics that in the music educational and musicological literature are often attributed to traditional (instrumental) music instruction (Chapter 2). These characteristics are a master-apprentice model, the primacy of the score and an alienation from the learners' daily reality. We elaborate on how these characteristics influence the different components of music instruction. Finally, we combine educational constructivism and the theory of embodied music cognition to formulate a possible alternative pedagogical approach (Chapter 3). In this approach, we emphasize the central and autonomous role of the learner, the construction of knowledge on the basis of concrete musical experiences, the importance of exploration and experimentation, and the role of the body for the development of musical abilities.

In PART 2 we develop the technological framework. We start with an overview of existing interactive music systems that aim at supporting instrumental music teaching and learning (Chapter 4, section 4.1). This overview is non-exhaustive but clearly shows that many interesting systems are being developed, in which visual feedback plays a prominent role. In most cases, the visual feedback is used to inform teachers and learners on different aspects of their playing (e.g. pitch/intonation, timbre). A growing number of systems also integrate sensors that enable motion tracking. As such, it becomes possible to also provide visual feedback on bodily aspects of music playing (e.g. posture, bowing gestures).

Next, we argue that these two features, namely visual feedback and motion tracking, can contribute to an embodied constructivist approach to instrumental music instruction (Chapter 4, sections 4.2 and 4.3). Interactive music systems are supposed to create a learning environment in which the subjective experience of the learner takes a central place. This way, learners can construct knowledge on the basis of their own experience. Visual feedback can support the construction of knowledge by influencing the cognitive processing of new information. By visually representing the effect of certain actions it is possible to accurately and unambiguously inform on the coupling between the action and the perceptual result of this action. As such, it becomes possible to correct or fine-tune the instrumental technique or musical expression. However, it is emphasized that visual feedback can also have a degrading effect on learning by introducing extra cognitive load or by creating a dependency on the feedback.

After the overview of existing systems and the elaboration on their potential to support an embodied constructivist approach, we present the interactive system that was developed throughout this research project (Chapter 5). This system, called the "Music Paint Machine", allows musicians to make a digital painting by playing a (traditional) musical instrument while moving the body. Similar to many other systems, it is based on monitoring sound and movement and gives visual feedback on the playing. However, we believe that the Music Paint Machine differs from most systems in a number of ways. To begin with, the system goes beyond the mere provision of information as knowledge of performance or knowledge of results. Based on the combination of music, movement and visual output, it rather seeks to invite learners to explore and experiment with music, the musical instrument, the body and the visual representation of movement and sound ("painting"). The emphasis is no longer on a cognitive control of the music based on iconically or symbolically represented information, but on the physical, auditory and visual experience of the music. Moreover, the Music Paint Machine attributes an active role to body movement in the sense that movements are not only monitored but also serve to control the system in combination with the sound. This way, we hope, the Music Paint Machine appeals to the bodily processes that underlie musical meaning making. We argue that by intensifying a bodily involvement with the music the learner can develop a bodily motility or freedom that allows immersing into the music while playing. This view is supported by the principle of *differential learning* (Schöllhorn, 2000) and by the *variability of practice hypothesis* (R. A. Schmidt, 1975). Both argue in favour of variability when exercising a particular technique. Variability is seen as an alternative for repeatedly trying to maintain a posture or execute a movement in the same prescribed way. We also argue that developing this freedom contributes to the development of an optimal relationship with the instrument.

In addition to stimulating exploration and experimentation, the Music Paint Machine can be used in function of specific learning goals. The system's mapping is so flexible that the translation of music and movement into the visualization can be adapted to the specific needs of a particular learning situation. As such, it is possible to introduce the learning content by starting with the concrete experience of interacting with the system. This experience can serve as the basis for the development of the symbolic or abstract knowledge related to that content.

In PART 3 of this thesis, we develop the experimental framework.

We start with an explanation of the rationale that underlies the development of the framework, namely the idea that the possible integration of the system in a naturalistic educational setting is the conditio sine qua non to arrive at a valid scientific investigation (Chapter 6). Accordingly, the research was guided by three objectives. The first objective was to adopt a pedagogy driven approach. We assert that the educational technology research needs to start from pedagogical-didactical concerns and goals, rather than celebrating the seemingly unlimited possibilities of diverse technologies (e.g. motion sensors) or software platforms. The second objective was to stay connected to the field of practice. We strongly belief that the Music Paint Machine and the research that was conducted with it, need to be relevant for daily instrumental music instruction. This implies that the knowledge and experience of teachers and learners are an important source of information for the development of the system. A third objective emerged throughout the research and concerns the focus of the empirical investigations. Gradually, it became clear that evaluating the effectiveness of an educational technology such as the Music Paint Machine couldn't be solely based on testing learning outcomes. It also needs to focus on the way the technology has an impact on the different components of instruction (learner, teacher, the interaction between both, the musical material or learning content). It became clear that an educational technology is much more than an independent variable that is inserted in the instructional process in order to induce an amplicative effect on the basis of its features.

Before we describe the experiments with the Music Paint Machine, we present a theoretical investigation of the relationship between musician and musical instrument (Chapter 7). We argue that an optimal relationship between the two involves the incorporation of the instrument. In other words, musician and musical instrument merge into a unity. We unravel the processes that underlie such an optimal relationship. This way, we were able to define the basic components of an embodied interaction with music. These components are: an optimal experience, direct perception and skill-based playing. We define an optimal or "flow" experience, in which a musician is completely absorbed in the act of playing music, as the combination of the feeling of presence and a positive emotional condition. The concept of presence originates in the research on computer generated virtual reality. In this thesis, we elaborate the concept within the embodied music cognition framework.

The theoretical investigation of the relationship between musician and musical instrument provided the basis for the concept of the Music Paint Machine but also for the experiments with the system.

The first experiment was a user study that probed the participants' personal experience with the system and their evaluation of its didactic potential (Chapter 8). We measured flow with the Flow State Scale (Jackson and Eklund, 2004) and presence with an in house designed questionnaire. This way, the measurement of presence was introduced in music research. Up until now, the concept of presence was only briefly referred to in the literature on music research (e.g. Leman, 2007). The results of this experiment suggested the system's potential to elicit a flow experience. They also provided an empirical validation of the intrinsic relationship between flow and presence (Chapter 9). With regard to the evaluation of the didactic potential, the results indicated that both students and teachers value the system as a way to support musical development and learning how to play a musical instrument.

The second experiment was a longitudinal study in which children learned to play the clarineo with the instructional support of the Music Paint Machine

(Chapter 10). In this study good practices were developed and the amplicative impact (focus on outcomes) of the system was tested on the basis of a non-equivalent control groups design. During nine months, twelve children received instruction on a weekly one-hour basis. Six children (two groups of three) received instruction with the Music Paint Machine, six children (two groups of three) received instruction without the system. The learning content was the same for the control and experimental groups. We investigated whether using the Music Paint Machine has an effect on the developmental music aptitude of the children. Music aptitude is a child's potential for music achievement that can develop during the first nine years on the basis of the child's musical experiences. According to Gordon (1986), the degree to which music aptitude develops also depends on the quality of formal music instruction. In our longitudinal study, we hypothesized that using an interactive music system that combines visual feedback and movement possibly contributes to the quality of instruction and thereby to the development of the children's music aptitude. We did not find a significant difference between the control and treatment groups with regard to the dependent variable, music aptitude. However, this study made clear that it is necessary to focus on the transformative impact (focus on processes) of technology. On the basis of the weekly lessons, it was experienced by the researcher-teacher that using the system has a deep impact on the classroom events during instruction. It became clear that integrating the system in instruction changes the way the teacher and the students relate to each other and the way instruction is organized. We believe that investigating these transformations needs to be part of music educational technology research.

In Part 4 of this thesis, we first describe the contributions of the research tat was presented in this thesis. Next, in the general discussion, we critically discuss different aspects of the research. This is followed by an outlook on future research and by a final conclusion.

List of Publications

- *Publications in peer-reviewed international journals*

  - NIJS, L., COUSSEMENT, P., MOENS, B., AMELYNCK, D., LESAFFRE, M. & LEMAN, M. (2012). Interacting with the Music Paint Machine: relating the concepts of flow experience and presence. *Interacting with Computers*, 24, pp. 237-250.

  - NIJS, L., MOENS, B., LESAFFRE, M. & LEMAN, M. (2012). The Music Paint Machine: stimulating self-monitoring through the generation of creative visual output using a technology-enhanced learning tool. *Journal of New Music Research*, 41(1), pp. 79-101.

  - DESMET, F., NIJS, L., DEMEY, M., LESAFFRE, M. & LEMAN, M. (2012). Assessing a clarinet player's performer gestures in relation to locally intended musical targets. *Journal of New Music Research*, 41(1), pp. 31-48.

  - LEMAN, M., M. LESAFFRE, L. NIJS & A. DEWEPPE (2010). User-oriented studies in embodied music cognition research. *Musicae scientiae*, Special issue: Understanding musical structure and form: papers in honour of Irène Deliège.

  in preparation:

  - NIJS, L. LESAFFRE, M. & LEMAN, M. The influence of a multimodal interactive educational technology on the developmental music aptitude: A longitudinal case study with the Music Paint Machine.

  - NIJS, L. LESAFFRE, M. & LEMAN, M. Integrating the Music Paint Machine in instrumental music education. A case study with three flute teachers.

  - NIJS, L., MÜLLER, C., LESAFFRE, M. & LEMAN, M. The musical instrument as a natural extension of the musician.

- *Bookchapters*

    - NIJS, L., LESAFFRE, M. & LEMAN, M. (in press). The Musical Instrument as a Natural Extension of the Musician. In: Castellengo, M. & Genevois, H. *Music and its instruments.* Sampzon, Editions Delatour France.

- *Publications in peer-reviewed international conferences*

    - NIJS, L., COUSSEMENT, P., MULLER, C., LESAFFRE, M. & LEMAN, M. (2010). The Music Paint Machine. A multimodal interactive platform to stimulate musical creativity in instrumental practice. In José A. Moinhos Cordeiro, Boris Shishkov, Alexander Verbraeck, Markus Helfert (Eds.): CSEDU 2010 - *Proceedings of the Second International Conference on Computer Supported Education*, Valencia, Spain.

    - NIJS, L., LESAFFRE, M. & LEMAN, M. (2010). Music performance and the mediality of acoustic musical instruments: an Activity Theory perspective. In *Proceedings of MeMCA*, Köln, Germany.

    - NIJS, L., LESAFFRE, M. & LEMAN, M. (2009). The Musical Instrument as a Natural Extension of the Musician. In *Proceedings of the Fifth Conference of Interdisciplinary Musicology*, Paris, France.

    - Lesaffre, M., Nijs, L. & Leman, M. (2009). Interacting with music mediation technology for hearing impaired - first tests with normal hearing subjects. In *Proceedings of the 7th Triennial Conference of European Society for the Cognitive Sciences of Music*, Jyväskylä, Finland.

- *Other publications:*

    - Nijs, L. (2011). Evaluatie in de instrumentles: pleidooi voor systematisering en explicitering. *Artishok* (6): Muzes vzw.

    - Nijs, L. (2010). Muziek in ieders lijf. Enkele beschouwingen over DKO, muziek en beweging. *Artishok* (4): Muzes vzw.

    - Nijs, L. (2008). Evaluatie in het deeltijds kunstonderwijs: het schietlood in actie. In P. Van Petegem e.a.(red). *Begeleid zelfstandig leren* (Alternatieve evaluatie 6, Afl. 21, pp. 1-40). Mechelen: Wolters-Plantyn.

INTRODUCTION

Music playing, interactive technology and music education

Music is pervasive in our lives. Whether shopping, jogging, driving or even working, music reaches us through a myriad of media, increasingly adding a soundtrack to our private, social and professional lives (Hargreaves & North, 1997). Next to the experiences of listening to music, people will always pursue to be actively involved in music. One way of doing this is to play a musical instrument. But learning to play a musical instrument is often a long and intensive process that might sharply stand in contrast to the plug and play devices of nowadays.

Plug and play is the rationale behind today's technology, which is another pervasive element in our lives. Interacting with computers has become part of our daily functioning. Moreover, ongoing technological developments (e.g. increasing computational power and expanding context through embedded computing) continuously change the way we interact with computers (Dourish, 2004). The traditional desktop computing is increasingly complemented and possibly even gradually replaced by a new breed of computational systems in which mouse and keyboard are exchanged for body and body movements as controller.

In the same way as technology has changed so many aspects of our daily activities, it has influenced music and music education. New ways of interacting with the computer have introduced new possibilities for listening and playing and for teaching and learning music. Plug and play devices and interactive music systems are developed to complement traditional music instruments (Addessi, Ferrari, Carlotti, & Pachet, 2006) or even to replace them (Denis, 2006). Digital monitoring systems are developed to complement classroom teaching and learning (e.g. Ng, Weyde, & Nesi, 2008), and on-line music tutoring systems are developed to stimulate practice (e.g. VEMUS; Fober, Letz, & Orlarey, 2007) or even to replace the teacher (e.g. Alfred's Teach Yourself series; www.alfred.com).

In this thesis, learning to play an acoustic music instrument and the use of interactive computer systems are linked to each other, based on the embodiment view as elaborated within the paradigm of embodied music cognition (Leman, 2007). In short, this paradigm states that musical experiences, whether it be listening or playing, have an indispensable corporeal ground. Body and body movement are constitutive to the musical signification process, mediating the translation from music as physical energy into music as subjectively experienced. With regard to playing music, it is assumed that the body movements executed during playing reveal something about the signification process of the player and the way he or she understands the music (Desmet, et al., 2012). Measuring the body movements therefore might reveal interesting aspects about the learning process. New sensing technologies enable the monitoring of movements. Embedding these technologies within an interactive computer system for music, hence interactive music systems, allows for a more or less (depending on the kind of sensors) unobtrusive measurement. Therefore interactive music systems play an important role within the embodied music cognition research paradigm.

The presented research was guided by the following research question:

> *How and to what degree can an interactive music system contribute to the development of an embodied understanding of music when learning how to play a musical instrument?*

This question entails the three key elements that define the why, what and how of instrumental music teaching and learning as conceived in this thesis (see Table 1).

Table 1. The why, what and how of music teaching and learning that constitute this research

WHY	Objective	Pedagogy	*Embodied understanding of music*
WHAT	Goal	Didactics	*Learning to play a musical instrument*
HOW	Condition	Technology	*Interactive music system*

The first key element is an *embodied understanding of music*. In our view, based on the theory of embodied music cognition and the pedagogical concept of constructivism, this element represents the pedagogical objective (why) of music teaching and learning. Developing musical understanding allows a meaningful engagement with music. But, what does it mean to have an embodied understanding of music? And, how can it be achieved? In chapter 2 and 3 these questions are addressed.

The second key element is *learning to play a musical instrument*. Playing a musical instrument is one of the many musical activities (what) through which musical understanding can be developed. Answering the above stated research question requires a thorough understanding of what is important when learning how to play a musical instrument. Which processes are involved? Where should these processes lead the student? In our view, the development of an optimal relationship with the instrument is an essential didactical goal of instrumental music teaching and learning. In chapter 2 and 3, we address the didactic aspects of instrumental teaching and learning. In chapter 7 the relationship between musician and musical instrument is investigated.

The third key element is the *interactive music system*. Learning how to play a musical instrument can take different forms. It can be, for example, formal or informal, teacher-centered or learner-centered, emphasizing technical or musical aspects, or supported by an educational technology or not. The use of educational technologies (e.g. an interactive music system) to learn how to play a music instrument creates a condition (how) that affects the way teaching and learning takes place. In our view, several features (e.g. using body movement, providing real-time visual feedback) of interactive music systems support the development of an optimal relationship with the musical instrument and the development of an embodied musical understanding. However, it is necessary to question the nature of the interactive music system that will be used in order to develop an embodied musical understanding when learning how to play a musical instrument. What kind of interactive system should be used? How should it be controlled? What does it do? In chapter 4, we will discuss the possible contribution of educational technologies to an embodied music cognition and constructivist approach to instrumental music teaching and learning. In chapter 5, we present the concept of the Music Paint Machine and outline its development.

We assume that the search for a possible answer to the above stated questions leads to the core of teaching and learning, urging to reflect upon the pedagogical objectives (*where could it lead us?*), the didactic goals (*what do we do to get there?*) and the learning conditions (*how do we organize learning and teaching?*) of instrumental music instruction. This might contribute to facing the challenges of the exciting changes in music education. These changes not only concern the use of new technologies as a way to align music education to the daily reality of our lives. It also addresses the philosophical foundations of music education.

What kind of music education in general and instrumental music instruction in particular do we want? What are the underlying ideas that influence the daily practice of teaching? Do we want new technologies to play a role? And the same holds for the research we do. What are the rationales behind the research on educational technologies? What kind of research should we do?

In this thesis we present a conceptual and empirical framework that was developed to find answers to these questions. The purpose of this research project was to develop an interactive music system that, both as a didactic and research tool, would enable us to answer the initial research question.

The interactive system that has been developed in this project is called the Music Paint Machine. It provides a game-like or playful environment in which a musician can create a digital painting by playing an acoustic musical instrument while moving the body in different directions and while selecting colours using a pressure mat (see Figure 1).

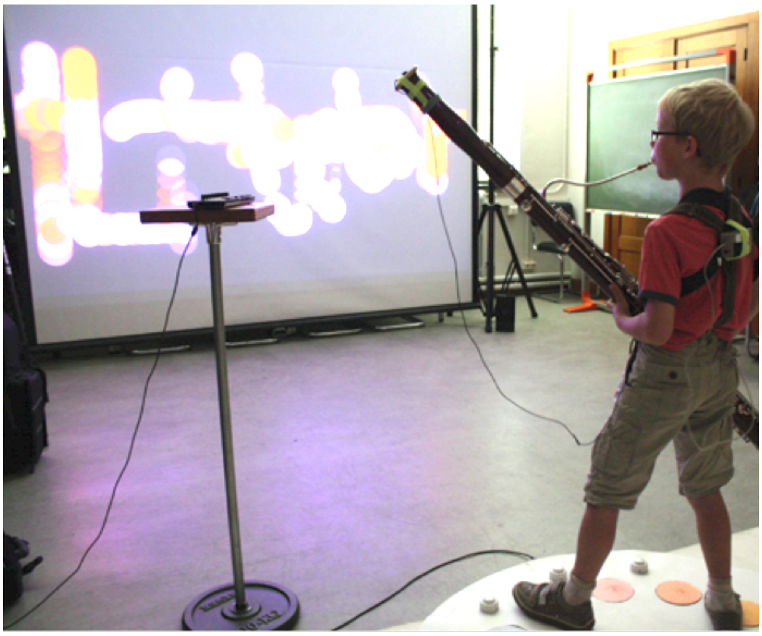


Figure 1. A young bassoon player improvising with the Music paint Machine

Throughout the research, an empirical framework was developed based on an iterative process between (1) a pedagogical framework based on constructivism, embodied music cognition and practice, (2) a technological framework for the development of the soft- and hardware, and (3) the experimental framework. This iterative process aimed at optimizing the potential of the Music Paint Machine through a 'spiral collaboration' (Addessi & Pachet, 2005) between the researcher, the soft- and hardware developers, the pedagogical experts and the users.

In chapter 6 the underlying rationale and aims of the empirical framework are outlined. Based on the idea that the possible instructional integration of the system in an ecologically valid educational setting is the conditio sine qua non to arrive at a valid scientific investigation, the empirical framework aimed at a research approach that is (1) driven by pedagogy, (2) connected to the field of practice, and (3) focused on the transformative impact of technology.

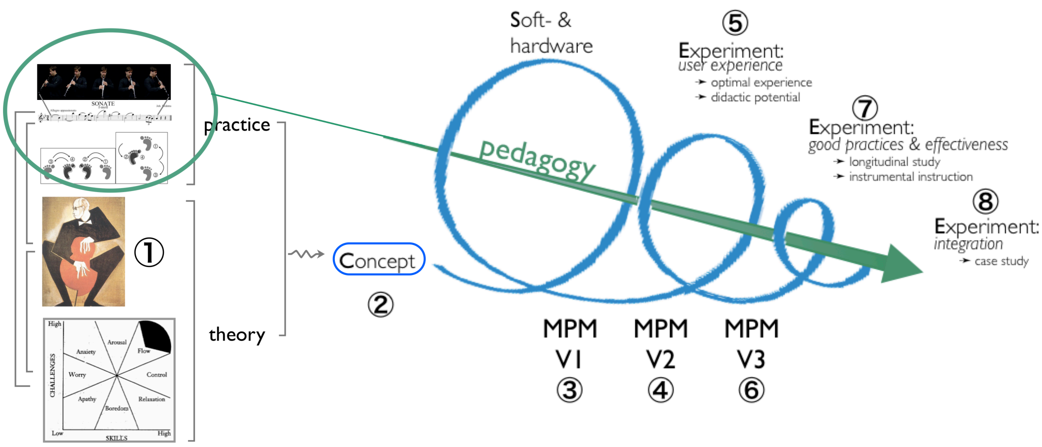


Figure 2. Visual representation of the empirical framework

The development of the framework entailed the following steps (see Figure 2):

1. An investigation of the relationship between a musician and the musical instrument (Chapter 7).
2. The design of the concept of the Music Paint Machine (Chapter 5)
3. The realisation of a first prototype (Chapter 5)
4. The realisation of a second prototype, after a pilot study (Chapter 5)
5. A study on user experience when engaging with the Music Paint Machine and on teachers' and learners' evaluation of the system's didactic potential (Chapters 8 and 9)
6. The realisation of a third prototype (Chapter 5)
7. A longitudinal study on learning how to play the clarinet with the Music Paint Machine (Chapter 10)
8. A case study on the instructional integration of the Music Paint Machine (Chapter 6).

We believe that our research makes a valuable contribution to the study of musical experience while engaging with an interactive music system. Our main contributions are:

- *the coupling of constructivism and embodied music cognition.* This led to a general pedagogical framework in which principles of constructivism (the idea that the learner constructs knowledge) are linked with the way in which knowledge construction can be most effective in music education, namely, through an approach that fully takes into account the role of the human body as mediator between knowledge and environment.

- *the elaboration of a contextual framework for the investigation of the relationship between musician and musical instrument.* This framework can provide a conceptual basis for the establishment of an empirical framework to investigate this relationship. We also believe that the Music Paint Machine might be an excellent tool for this empirical investigation.

- *the elaboration of the relationship of flow and presence within the theory of embodied music cognition.* In our research we developed a questionnaire to probe presence when engaging with an interactive music system. Bringing the construct of presence in the domain of interactive music systems might broaden the use of presence towards research on artistic expression and creativity. Findings from a user study empirically validated the theoretically elaborated relationship between flow and presence.

- *the development of an empirical framework for the research-based design of an interactive music system and for the study of the potential role of such a system in instrumental music teaching and learning.* Although the framework needs further development, important steps have been taken to establish a pedagogy-grounded and practice based research framework.

- *the development of a technology-enhanced music instrument learning system, based on interactive technology.* This system is still in a proto-type phase but the particular nature of the system (the unity of body and instrument as controller of the system, the creative use of visual feedback) provides an excellent opportunity to study the role of visual feedback, the use body movements and their integration when learning how to play an instrument.

- *an embodied approach to instrumental music learning:* in this thesis, ideas are presented that contain the germ of a new approach to instrumental music teaching and learning, on the basis of a creative use of the body

It is our sincere hope that the results of the presented research may stimulate other educators and researchers to expand on this work in the domain of music education and music education (technology) research and to raise it to the next level.

PART 1: PEDAGOGICAL FRAMEWORK

CHAPTER 1

Instrumental music instruction and its components

In our Western society a rich variety of both formal and non-formal educational systems offer instrumental music instruction to those who want to learn to play a musical instrument (e.g. Tchernoff, 2007). One such educational system is formal instrumental music instruction or applied music instruction. It is typically provided in general or specialized music schools (outside compulsory school). This kind of instruction implies a specific environment in which teaching and learning takes place between a small group consisting of a teacher and one or a few students. According to Kennel (2002) the applied music instructional system is characterized by four components, namely the learner, the musical artefacts, the teacher and his/her expertise and the interaction between teacher and learner (see Figure 4).

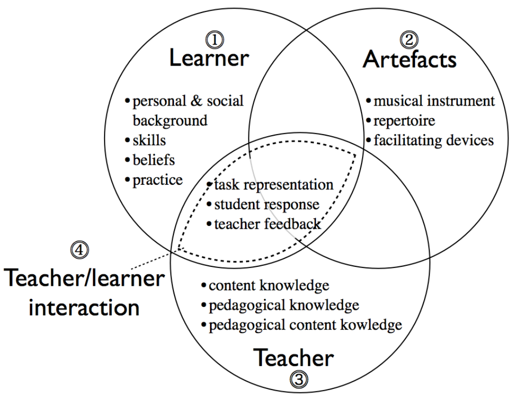


Figure 1.1. The four components of instrumental music instruction according to Kennel (2002).

A first component is the *learner* who attends instruction to acquire the necessary skills in order to become a fine musician. Far from being an empty vessel, the learner brings to the classroom a rich baggage of personal (e.g. age, gender) and social (e.g. education, family) backgrounds and experiences. Prior to music instruction, the learner has built a set of intellectual, physical, technical and communicative skills and already developed personal beliefs and aspirations on learning how to play a musical instrument. The latter distinctly influence, for example, motivation and the achievement goals of the student (McPherson, 2006). This component is also related to the learner's instrumental practice. Research on the nature of expertise has indicated the importance of both the amount and quality of practice (Ericsson, Krampe, & Tesch-Römer, 1993). Scholars also pointed out the importance of parental support for practicing to play a musical instrument (e.g. Hallam, 2006; McPherson & Davidson, 2002; Zdzinski, 1992).

A second component consists of the *musical artefacts* that are involved in instrumental music instruction. The central artefact obviously is the musical instrument itself, which is complemented by the music repertoire that is used in the lessons. Each instrument has its specific repertoire of etudes, solo pieces, concerto's and chamber music pieces. Additionally, different facilitating devices such as for example a music stand, a piano, a blackboard, a metronome, a tuner, visual representations (e.g. of rhythms, fingering chart) or a computer might be used in the classroom.

A third component is the *teacher and her/his expertise*. It includes the performance and teaching expertise, on the basis of which the teacher makes decisions to shape and control different aspects of instruction. Effective teaching has been linked to the so-called pedagogical content knowledge (PCK), that is, the blending of content and pedagogical knowledge into an understanding of how particular aspects of subject matter are organized, adapted and represented for instruction (Shulman, 1987). This kind of knowledge goes beyond the mere sum of content knowledge (about the subject matter) and pedagogical knowledge (about teaching and learning). Research has indicated that a teacher's level of expertise has an impact on important aspects of instruction such as the amount of verbal instruction and feedback (e.g. Goolsby, 1997), time allocation (Duke, 1999a) and pacing (e.g. Duke, Prickett, & Jellison, 1998), and content (e.g. Goolsby, 1997; Young, Burwell, & Pickup, 2003).

A fourth component is the *teacher-learner interaction* during instruction. This interaction is found to be very complex. To begin with, it has been argued that the teacher-learner interaction encompasses a series of subcomponents (Kennell, 2002). From this perspective, music instruction consists of different segments or "rehearsal frames" (Duke, 1994, 1999a), combined into instructional cycles of task presentation, student response and teacher feedback (e.g. Yarbrough, Price, & Hendel, 1994). Each of these segments might be characterized by a specific kind of interaction. Next, applied music instruction is often characterized by spontaneity and "on the spot" teaching (Elliott, 1995; Jorgensen, 2008). According to Kennel (2002) this might be the consequence of less pre-lesson production of elaborated teaching plans. Finally, an important determinant of the teacher-learner interaction is the nature of relationship between the teacher and the learner. Lehman, Sloboda and Woody (2007) distinguish two broad models. A first model is the *master-apprentice* model, which is based on the teacher's verbal explanation of experience and demonstration (often aural modelling) of musical craftsmanship. A second model is the *mentor-friend* model, which is based on a greater exchange between teacher and learner. We believe that both models can be seen as the extremes of a continuum. In real life, the interaction between teacher and student will more likely be dynamically positioned on this continuum than being fixed throughout a learner's musical education.

It is assumed that the way that instruction is approached has an impact on these components, their interaction and their position within the learning environment. In the next chapter we elaborate on the traditional approach to music instruction, starting from three characteristics that are currently under scrutiny. These characteristics are related to the nature of the relationship between the teacher and the learner, to the role of the score and to the learner's daily reality.

CHAPTER 2

Characteristics of instrumental music instruction

In recent years, a number of characteristics of music education (e.g. teaching style, curriculum) within the Western tradition of art music have come under scrutiny. More and more critical considerations of these characteristics are supported by empirical and theoretical research, which resulted in an emergent dichotomy between "traditional" and "alternative" approaches to music teaching and learning. In the research literature on music education, traditional approaches are often attributed a number of characteristics that seem to be in conflict with current pedagogical insights. We believe that this critical scrutiny needs to be considered with caution. First, the denomination as "traditional" is sometimes used inconsistently or without explicitly explaining what is meant by it. Second, the number of existing studies on instrumental music is still scarce (Kennell, 2002; Mills, 2004; Triantafyllaki, 2005) and, accordingly, the creativity and constructive approaches of many individual teachers can be overlooked by making generalisations based on the limited number of participants in these studies. Third, these critiques are often about different systems of music education such as general music teaching, teaching in a choir or band, or applied music instruction. As such it is not always possible to entirely apply the critical considerations to just any teaching context. Nevertheless, it is necessary to take the various critiques of both practitioners and scholars seriously and see how they can be used to bring about educational changes and innovations. In the next paragraphs, an overview of the most frequently mentioned critiques will be given and elaborated upon in an attempt to provide an annotated overview of the characteristics of, what we will call, a "traditionalist"[1] music education. These characteristics are: a prevailing master-apprentice model, the primacy of the score and an alienation from the learner's world of experience.

2.1. The master-apprentice model

The so-called "traditionalist" approach to music instruction is often presumed to be characterized by the prevalence of a master-apprentice model (e.g. Bowman, 2002; Hennessy, 2001; Lehmann, Sloboda, & Woody, 2007). Several aspects of this model can be problematized from a pedagogical viewpoint.

One such aspect is the teacher-centeredness of this model of instruction. Lessons are found to be mostly individualistic and teacher controlled (e.g. Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). That is, the teacher chooses what each individual learner has to play (repertoire), determines how to approach it (practice) and prescribes how to play it (interpretative and expressive details of performance) (e.g. Bartel & Cameron, 2004; Woody, 2007). Learning outcomes are planned (e.g. what to play and when), monitored and assessed according to predefined technical and interpretative standards. These standards are often passed from one generation to another (e.g. belonging to a certain school such as the Russian piano school or the Franco-Belgian violin school).

Another allegedly problematic aspect of the master-apprentice model is its governing didactic practice. Following the teacher-centeredness, teaching within this model is supposed to be based upon a didactics of transmission and reproductive imitation (Olsson, 2009). The teacher or "master", who is a role model, passes on his knowledge and expertise in a mainly one-way communication from teacher to learner. This often results in the learners' merely copying of the master's model (e.g. Young, et al., 2003). Not surprisingly, such traditionalist teaching focuses on the music as a product, exemplified in this master's model.

A final questionable aspect of the master-apprentice model concerns the way knowledge is transmitted. Teaching is mainly dominated by verbal instruction

[1] Here we introduce the difference between "tradition" and "traditionalist" to distinguish between a set of practices that were developed and proven fruitful over time and a dogmatic adherence to "a collection of bad habits" (Schnabel & Crankshaw, 1988).

and feedback, and by aural modelling (e.g. Lehmann, et al., 2007). This easily leads to a cognitive-analytic approach of musical content and an imitation of the master's model without really understanding it.

These different aspects of the master-apprentice model have important repercussions on the learner's development. The focus on repetitive imitation and aural modelling might hinder the learner's self-responsibility and neglect the individual artistic voice (Gaunt, 2009). The dominance of verbal explanation might lead to a disembodied approach, i.e. detached from the actual experience of the music, in which extrinsic (verbal) feedback prevails over intrinsic feedback mechanisms. The lack of autonomy might influence learner's (intrinsic) motivation and self-regulation skills (Schunk, 1991).

2.2. A score-based approach

In traditionalist music instruction, the score supposedly plays the central role. According to different scholars (e.g. Bartel & Cameron, 2004; McPherson & Gabrielsson, 2002) traditional music teaching is mainly based on the reproduction of written music. Students have to learn to decode notation (read) and replicate (play) the composer's intentions as understood by the "master". Again, several aspects of this characteristic can be criticized from both a pedagogical and musical point of view.

First, the score based nature of traditional music instruction leads to a focus on formal knowledge and skill acquisition (Bamford, 2007). Knowledge is assumed necessary to understand a composition and is to a large degree gained through the (verbal) descriptive analysis of the composition. Skills are necessary to reproduce the composition as authentically and perfectly as possible. A learner must acquire sufficient technical skills to master the musical instruments to the degree of being able to adequately reproduce the piece.

Second, the focus on the reproduction of written music leaves less space for playing by ear, for improvisation and for composition. Yet these learning methods are essential to develop musical creativity (e.g. Deliège & Wiggins, 2006; Koutsoupidou & Hargreaves, 2009). Consequently, traditionalist music instruction is often criticized for insufficiently stimulating the learners' creativity.

The score-based approach and its emphasis on the technical perfection of the reproduced repertoire have several possible implications for both teaching and learning. For example, this approach easily favours a linear conception of technique and musical expression. Prior to the development of musical expression comes the control of the body and the instrument in order to develop the necessary technique that might enable, afterwards, the expressive performance of a composition. Here, the body and the musical instrument are conceived as mere tools that serve to reproduce the written music. Playing music becomes a matter of mastering the body and the instrument in function of an "authentic" interpretation rather than a matter of experiencing the music and expressing oneself. This might be an important reason for the fact that teaching is often limited to the technical aspects of playing, at the expense of expressiveness and interpretation (Heikinheimo, 2009; Persson, 1994; Rostvall & West, 2003). Remarkably, this instrumentalist way of thinking about body and instrument is in contrast with an intuition that is shared by many musicians, namely the feeling that the musical instrument has become a part of the body (see Chapter 7). Here, playing music is experiencing the music without being preoccupied with the tools to (re)produce the music. Body and instrument merge into a unity that, as a semantic tool, allows to "read the mind of the composer" through the process of corporeal intentionality, i.e. a corporeal resonance with the music (Leman, 2007).

Furthermore, an emphasis on notation might lead to a decrease in learners' sensitivity that allows the spontaneous perception of patterns when listening to music (McPherson & Gabrielsson, 2002). Playing becomes guided by the coupling of notation to fingerings instead of coupling it to sounds. Consequently, practice habits might not be driven by the ear (Lehmann, et al., 2007).

2.3. Alienated from the children's life world

Next to being attributed a master-apprentice model and a score-based approach, traditional music instruction is often proclaimed to have alienated from the daily reality of those that are being taught. According to Sloboda (2001) music educators have little respect for or understanding of the musical lives of the learners. Consequently their musical enthusiasm and aspirations are not addressed by the current curriculum. Bolden (2009) noticed that students are sometimes even forced to exclude their own musical preferences from the classroom.

The neglect of the learner's world of experience affects the way a learner perceives the meaningfulness of the instruction. It often leads to a decrease in motivation and to early drop out (Sloboda, 2001).

To sum up: a traditionalist approach, characterized by a master-apprentice teaching model, a primacy of the musical score and an alienation from the learner's world of experience, might create a learning environment that, in view of recent pedagogical insights, is definitely prone to criticism. In table 2.1, we present and overview of the three characteristics and their aspects.

Table 2.1. A non-exhaustive overview of the scrutinized characteristics of "traditionalist" music instruction.

MASTER-APPRENTICE MODEL	SCORE-BASED APPROACH	ALIENATION FROM THE LEARNER'S DAILY REALITY
• teacher-centered • transmission & reproductive imitation • verbal explanation/feedback & aural modelling	• focus on formal knowledge & skill acquisition • not ear-based • no improvisation & composition	• neglect of learner's "own" music • curriculum neglects the learner's aspirations
↓	↓	↓
◦ reduced autonomy ◦ neglect of individual artistic voice ◦ less intrinsic motivation	◦ verbal explanation & aural modelling ◦ focus on technique ◦ focus on classical canon ◦ control vs experience ◦ less musical sensitivity	◦ decrease in perceived meaningfulness ◦ drop out

Each of these characteristics has an impact on the different components of instrumental instruction (see Table 2.1). For example, the master-apprentice model determines the interaction component by establishing an asymmetric relationship between the teacher and the learner, leading to a reduced autonomy of the learner. It also affects the artefact component by focusing on specific repertoire, often the canon Western classical music. Finally, it influences the skills (e.g. self-regulation), practice methods (do as the master tells and neglect of individual artistic voice) and motivation (less intrinsic). The score-based approach affects, for example, the interaction component by adhering to verbal explanations and aural modelling. It influences the artefact component by focusing on the score and the learner component by focusing on reproduction skills at the expense of improvisation and composition skills. The alienation from the learner's daily reality has, for example, an impact on the artefact component by banishing certain repertoire and on the learner component by affecting autonomy and motivation. This often leads to a reduced meaningfulness of the lessons for the learner and often to drop out from the curriculum (e.g. Costa-Giomi, Flowers, & Sasaki, 2005; Hallam, 1998; Rados, Kovacevic, Bogunovic, Ignjatovic, & Acic, 2003). From this non-exhaustive list of examples, it becomes clear that the traditionalist approach to instrumental music teaching and learning leads to a learning environment in which the centrality of the teacher severely determines instruction's pedagogical objectives, didactic goals and conditions.

To conclude, we believe that it is important to realize that most likely the degree to which this traditionalist way of teaching occurs in the daily music classroom varies from teacher to teacher, based on which aspects are emphasized throughout the lessons. Despite the list of problematic elements of traditionalist teaching, this very way of teaching has generated numerous great musicians. A lot more research in ecological settings is needed to acquire a comprehensive, and perhaps more nuanced, view on the nature of (instrumental) music instruction.

CHAPTER 3

A possible answer to a traditionalist approach to music instruction: educational constructivism and the theory of embodied music cognition

A possible answer to the critiques on traditionalist music instruction can be found in two - related - theoretical frameworks. One is *educational constructivism*, which is a “meaning-making theory” (Paul & Ballantine, 2002) that emphasizes the active role of the learner and the social nature of learning. The other is the theory of *embodied music cognition* (Leman, 2007), which emphasizes the essential role of the body in the construction of musical meaning. In the following paragraphs, both theoretical frameworks will be shortly outlined and elaborated on with regard to the aforementioned critiques on traditional music instruction.

3.1. Educational constructivism

Constructivism is an important force in contemporary thinking on education (P. R. Webster, 2011a). It is a theory about knowledge and learning that goes back to the writings of Dewey, Piaget, Bruner and Vygotsky. Today a variety of beliefs, approaches and strategies exist under the umbrella of the notion of constructivism (Maréchal, 2009; Pritchard & Woollard, 2010; Schunk, 1991). Here we will not go deeper into these different currents but rather elaborate on the underlying common principles. These principles are the construction of knowledge, the learner's active role, and the determinant role of the (social) learning environment.

3.1.1. Constructing knowledge

Constructivism argues that learning is based on the construction of knowledge through the learner's interaction with the environment. Learning is a sense-making activity in which the learner selects, organizes, and integrates new information with existing knowledge (Moreno & Mayer, 2007). The selection, organization and integration of knowledge are assumed to be based on mental schemas (Ormrod, 1990), which are the cognitive structures that guide the interaction with the environment. The construction of knowledge then involves a dialectic process in which existing schemas are accommodated to new information or new information is assimilated into existing schemas[2] (Piaget, 1954). As such, the learner actively builds the schemas by repeatedly engaging in similar activities. In this way a network of context specific bodies of knowledge is constructed that can be applied to specific situations (Widmayer, 2005).

According to von Glasersfeld (1989), schemas consist of three parts, each of which is concerned with one of the following functions:

- *the recognition of a certain situation, based on the perception of certain stimuli*
- *the association with a specific activity*
- *expectation of a certain result.*

As such, schemas are related to the abilities of remembering and retrieving (re-presenting) information and of comparing and judging on differences and similarities. Recognizing a situation, associating it with an activity and re-presenting it to judge differences and similarities are based on the tight action-perception couplings that are realized by the schema (Pezzulo, 2007).

Action-perception couplings allow the comparison of an anticipatory model that represents the expected outcome of an action. If the actual outcome matches the expected outcome, the information is assimilated into the activated

[2] In this thesis, 'schemas' (e.g. Pezzulo, 2007) or 'schemes' (e.g. Rabardel, 2002) both refer to the plural of schema, i.e. a cognitive structure that guide the interaction with the environment

schema. If they do not match, adaptation of the schema is necessary. The repeated activation of the schema and the experience of its success in mediating the interaction, leads to the automation of the schema. Automated schemas act as a central executive that directly steers behavior without the need to be processed in working memory (Van Merriënboer & Sweller, 2005).

Schema acquisition and schema automation are assumed essential components of learning (Sweller, Van Merrienboer, & Paas, 1998). Evidently, the nature of instruction, i.e. which and how information is presented to the learner, has an impact on schema acquisition and learning (Van Merriënboer & Sweller, 2005).

3.1.2. The active role of the learner

Within the constructivist view, the learner plays a pivotal role in the learning process. Without dismissing the essential role of the teacher or the value of expert knowledge, the autonomy of the learner is emphasized so that learning can increasingly become a self-regulatory process. Self-regulation encompasses various aspects such as goal setting, self-observation, self-assessment, and self-reinforcement, all of which are believed to influence learning (Loyens & Gijbels, 2008). The teacher takes on a facilitating role, creating an environment that stimulates learners to effectively take control over their own learning process (Svinicki, 2008). Supporting the learner's autonomy involves providing different options and opportunities to choose and decide on different elements of the learning process. However, this is far from being an "anything goes" pedagogy in which the learner does whatever he or she wants. Rather, the teacher models decision-making processes and carefully scaffolds the choices that are given (Wigfield, Tonks, & Klauda, 2009).

Acknowledging the importance of learner autonomy implies a learner-centered approach in which exploration and experimentation are valued as viable ways of learning. Both musical activities allow learners to learn by discovery (Bruner, 1979). That way they learn to recognize a problem, characterize what a solution might look like, search for relevant information, develop a solution strategy, and execute the chosen strategy. However, exploration, experimentation and discovery learning should be used with precaution. Discovery learning covers a variety of teaching methods, all of which share the idea that the target information must be discovered by the learner within the confines of the task and its material (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011). The learner needs to make sense of the presented learning content by selecting relevant new information, organizing the information into a coherent structure and integrate it with existing knowledge (building and developing schemes). But this is a very demanding process. It limits working memory and as such might hinder learning (Mayer, 2004). Therefore, the role of the teacher is essential. Different teaching strategies such as *generation* (generate ideas and explain their thinking), *elicited explanation* (explain some aspect of the target task or target material) or *guided instruction* (e.g. scaffold or give feedback) can enhance discovery learning and turn it into an effective instruction method (Alfieri, et al., 2011). Another method concerns the way teachers design activities and thereby constitute the learning environment. This is elaborated in the next section.

3.1.3. Constructing the learning environment

A constructivist approach to teaching and learning is all about the purposeful design of a context that allows learners' discovery, stimulates the construction of knowledge and fosters the active role of the learner. Providing learners with an environment rich of accessible and meaningful affordances, i.e. invitations to act (Gibson, 1979), and designing tasks with multiple entry points helps them to scaffold their own learning and assist in the learning of others (Custodero, 2010a, 2010b). This way, a context is created in which students are given the opportunity to experiment and explore with a carefully selected content and with the content that spontaneously emerges through the interaction between learner, teacher and task.

According to Bransford (Bransford, 2000) an effective – or: Powerful (De Corte, Verschaffel, & Masui, 2004) – Learning Environment (PLE) is characterized by four interconnected basic features, namely learner-centeredness, knowledge-centeredness, assessment-centeredness and community-centeredness (see Figure 3.1).

First, a PLE is *learner-centered*. It fosters knowledge construction and skills acquisition on the basis of the learners' current knowledge and skills, their personal interests and beliefs, and their attitudes. Additionally, a learner-centered learning environment cultivates the learners' autonomy.

Second, a PLE is *knowledge-centered*. It helps learners to develop the necessary domain knowledge and to acquire the necessary skills to support future thinking and learning. The learner is provided with clear goals. This feature also includes the development of self-monitoring and self-regulation.

Third, a PLE is *assessment-centered*. In such an environment the learners are provided with frequent formal and informal opportunities for feedback that contains the relevant information to develop genuine understanding, as opposed to the mere memorization of knowledge. Summative assessment, i.e. formal testing at the end of a period in function of marks and grades, is complemented with formative assessment, i.e. assessment during the learning process, in order to provide learners with opportunities to revise and improve the quality of their thinking and understanding. This way, the development of self-assessment skills is stimulated.

Fourth, a PLE is *community-centered*. It establishes the norms that support collaboration and pertain to the micro (classroom), meso (school) and macro (broader community) level of the learning environment. It stimulates collaborative learning and dialogue.

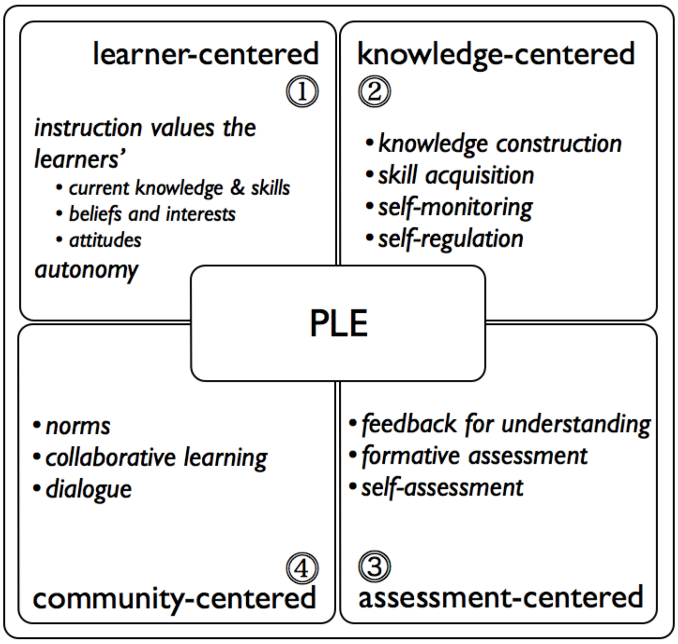


Figure 3.1. The four characteristics of a Powerful Learning Environment and their different aspects.

Furthermore, an effective learning environment is characterized by a balance between discovery learning and personal exploration on the one hand, and systematic instruction and guidance on the other hand (Schelfhout, Dochy, & Janssens, 2004).

A last characteristic of a powerful learning environment is its ability to elicit an optimal or *flow* experience (Shernoff & Csikszentmihalyi, 2009). By being learner-, knowledge-, assessment- and community-centered and by combining exploration and guided instruction to shape the learner's development, such a learning environment will foster the conditions of flow, which are a balance between skills and challenge, unambiguous feedback, and clear goals every step of the way (Chen, Wigand, & Nilan, 1999). This will positively affect the learners' engagement by stimulating the intensity of the learning (concentration, interest, attention) and a positive response (esteem, enjoyment, intrinsic motivation) (Shernoff & Csikszentmihalyi, 2009).

In the next paragraph the constructivist principles as outline above are applied to instrumental music instruction. This paragraph is not meant to give an exhaustive overview. It rather entails some didactical reflections on possible directions to shape instruction. Concrete examples are given to illustrate the reflections.

Implications for instrumental music instruction

The core of music instruction is to cultivate musicianship, which involves the dispositions and abilities that allow a musically informed perception and production of music (Bowman, 2004). To achieve this overall objective, instrumental instruction has two major goals, namely the development of musical understanding and the development of the necessary skills to play the instrument. Both goals are interdependent (Sloboda, 2000). Obviously, the nature of instruction determines the degree to which the processes of developing skills and musical understanding relate to each other and determine the musical learning process.

According to constructivism, the musical learning process must have two essential characteristics. First, knowledge must be constructed throughout meaningful experiences and on the basis of existing knowledge. Second, and following the first characteristic, the learner must not be a passive receiver of knowledge, but play an active role in the learning process. Fostering these characteristics implies a specific learning environment.

Constructing musical knowledge

Because the construction of musical knowledge involves connecting the presented musical learning content to existing knowledge, a constructivist approach to musical teaching and learning acknowledges the learners' past (musical) experiences, in and out of the classroom. For example, a teacher can start from known songs to introduce new content instead of merely going to the next chapter of the method book. Or technical exercises can be complemented with an accompaniment in the preferred style of the learners. This decreases the risk of adhering to a curriculum that does not appeal to the learner's daily reality. Accordingly, the dialogue between learner and teacher becomes an important method to gain insights in the learner's experiential world. The asymmetric relationship of the master-apprentice model is transformed into a symmetric relation in which the beliefs, expectations and intentions of the learner are valued as possible starting points of new learning experiences. Showing interest in the learners' musical and other experiences outside the classroom allows teachers to connect to the students and to establish a relationship of mutual appreciation.

Related to the constructivist viewpoint on knowledge construction is the way the learning process is built up. The rationale behind the construction process is to start from concrete experiences and to develop towards abstract symbolic reasoning. This has, for example, implications on the introduction of music theoretical content and on the function of the score in instrumental music instruction. Making the act of playing music dependent on a score from the very beginnings emphasizes symbolic or abstract knowledge (Bruner, 1966, 1979), possibly at the expense of the enactive knowledge that is shaped through concrete experiences. For example, coupling duration to note values from the very start might lead to a mere "counting" of beats instead of "feeling" the length of a note.

The need to start from concrete musical experiences therefore pleads for ear-based playing and for (guided) exploratory improvisation. By building up a series of experiences in which learners collaborate to construct knowledge, the teacher can guide them towards a certain learning goal. For example, learners can collaboratively built a rhythmic pattern on the basis of known rhythmic building blocks. Afterwards they can improvise on this self-made rhythmic pattern. Choosing rhythmic building blocks, constructing a nice sequence with them and adding a melodic contour to the rhythmic pattern, are concrete experiences that may be used to introduce more abstract content such as phrasing or endings.

The active role of the learner

Next to the construction of knowledge, the active role of the learner is a cornerstone of a constructivist approach to music instruction. Therefore, in contrast to the teacher-centered approach of transmitting knowledge through the verbal description and aural modelling of the musical learning content, a constructivist approach to teaching and learning fosters a learning process in which learners become responsible for the inquiring and ultimate meaning making (Custodero, 2010a).

Acknowledging the active role of the learners also implies accepting their autonomy. Consequently, learner must be able to make choices with regard to repertoire. As such learners can integrate the musical learning process within his or her personal world of experience. This might have its repercussion on the primacy of the canon of Western art music. On the other hand, the learners' choice of repertoire might be a starting point to introduce a repertoire that is specific to the instrument. For example, an etude that focuses on a specific instrumental difficulty might be introduced by a song or composition that appeals to the learner's preferences and contains the same difficulty. Being confronted with this difficulty in this song or composition, the learner might become more motivated to practice the study.

To sum up, the constructivist approach to teaching and learning provides an alternative to the traditionalist approach that is often applied in instrumental music instruction. It does so by:

- *promoting the autonomy of the learner by means of a learner-centered approach*
- *substituting the transmission of knowledge with the (co-)construction of knowledge*
- *acknowledging the importance of exploration and improvisation*
- *valuing the learners' preferences, beliefs and musical aspirations as a lever for learning*
- *creating an environment that stimulates an optimal learning experience*
- *fostering the learners' intrinsic motivation*

In these ways, a constructivist approach to instrumental music instruction contributes to the learners musical understanding and autonomous meaning-making. But while the constructivist approach emphasizes the active role of the learner in the construction of knowledge, the actual processes that underlie the construction of knowledge and meaning are less elaborated. Understanding these processes is important to further develop the didactic methods of instrumental instruction in such a way that they support the development of an *embodied* understanding of music. In the next section, we turn to the theory of embodied music cognition to elaborate on the corporeal basis of musical understanding and its implications for instrumental music instruction.

3.2. Embodied Music Cognition

Complementary to the constructivist approach, the embodied music cognition paradigm may function as an important source for a didactic approach that counters the shortcomings of the so-called “traditionalist” music instruction. While constructivism stresses the importance of the learner’s engagement in a sense-making activity in order to construct knowledge, the embodied music cognition paradigm stresses that the basis of such sense-giving activity is provided by corporeal experiences (Bowman, 2004; Leman, 2007; Godoy and Leman, 2010).

3.2.1. The body as the natural mediator of experience

The core idea of the embodied music cognition paradigm concerns the mediating role of the body when engaging with music. The body is believed to bridge the gap between musical experience and sound energy (Leman, 2007). Accordingly, musical experience is assumed to have a firm and indispensable corporeal ground (e.g. Bowman & Powell, 2006; Godoy & Leman, 2010; Leman, 2007). It involves a bodily presence that goes beyond a merely sensual ‘response’ to an auditory ‘stimulus’ and that functions as a fundamentally constitutive element of the musical experience (Bowman, 2004).

According to the theory of embodied music cognition, the mediating role of the body lies in the process of corporeal intentionality, i.e. the process of turning the physical energies of the music (e.g. frequency, amplitude) into an imaginary world of objects having qualities, valences, goals and intentions (Leman, 2007). This process is an emerging effect of the action-perception couplings of the musician. Action-perception couplings are the result of embodied skills, knowledge and experience and allow a pre-reflective attunement between the musician and the musical world that is created through a music performance. It is assumed that, through a process of corporeal imitation, learned schemas of action-perception couplings are used to transform patterns of sound into corporeal articulations, i.e. structures, patterns and gestures from our embodied existence and actions (Bowman, 2004; Leman, 2007). That way it becomes possible to corporeally resonate with the music and to rely on an experiential – corporeal – basis to give meaning to the music and to develop musical understanding. Such corporeal attunement with the music is characteristic for what is called an embodied interaction with music, an experience in which the musician participates in a direct and engaged way in the musical environment he or she creates while playing (Dourish, 2004).

An essential element of the pre-reflective attunement and crucial to the possibility of freely resonating with the music is the body’s original motility. This is the possibility of the body to move spontaneously and it is related to the body as vehicle of being part of and experiencing the world (Behnke, 1989; Dant, 2004). Motility, in its pure state, possesses the basic power of giving meaning to the world. According to Merleau-Ponty (1945), it is the primary sphere in which all significance is initially engendered. It opens a whole space of possibilities (i.e. potential movements) to experience the musical world by allowing the musician to perceive and respond to the affordances of the music. These are the elements in the music that invite the musician to attune to the music on the basis of the cross-modal transfer of previously bodily-acquired schemas to the inviting musical elements. These schemas form the so-called action–oriented or action-intended ontology and allow understanding the music on the basis of "the active creation of an intentional world, in which inert sounds are transfigured into metaphorical gestures in a metaphorical space" (Scruton, 1983).

The corporeal basis of music cognition supports the idea that musical meaning is not solely based on a perceptual analysis of musical structure but to an important degree on bodily action. When playing a musical instrument this bodily action is determined by the instrument (e.g. the specific position when playing violin, the sitting position when playing cello or piano). Therefore, the musical instrument can be assumed to have an impact on the original motility of the (beginning) musician and, consequently, on the corporeal resonance with the music. The next section elaborates on the musician-instrument relationship from the viewpoint of embodied music cognition (see also Chapter 7).

3.2.2. The musical instrument, an artificial extension of the natural mediator

The theory of embodied music cognition asserts that the body, being the natural mediator, can be extended with an artificial mediator such as a musical instrument. The nature of this extension is vital because it may allow or hinder an embodied interaction with the music as described above. It is important for the tool not to interfere with a direct engagement with the music. This is only possible when the musical instrument (or any other musical tool) becomes incorporated into the natural mediator (see Chapter 7). When this happens, the body can be restored in its original motility, which has been disturbed when starting to play the instrument. In figure 3.2, it is shown how the musical instrument has an impact on musical meaning making.

In short, when the instrument blocks the bodily motility it interferes with an embodied interaction with the music. Consequently, it becomes difficult to engage directly with the music and to intuitively (without conscious processing) understand it. This affects the way meaning is extracted. An embodied interaction is presumably only possible when the music can be perceived directly, i.e. picking up musical information without the need for conscious cognitive processing, and when playing music is skill-based, i.e. automatically generating the adequate responses. Direct perception enables the process of corporeal imitation, i.e. capturing the intentionality of the music by translating the music into bodily experiences; skill-based playing enables the process corporeal articulation, i.e. the corporeal expression of the intentionality of the music (Leman, 2007). Both processes, corporeal imitation and articulation, are the result of emerging action-perception couplings. Therefore, it is necessary to develop the necessary mental schemas, which allow the direct perception of the music and a skill-based playing. To achieve this, the musical instrument needs to be incorporated into the body schema, which determines the possibilities to perceive and act (see Chapter 7).

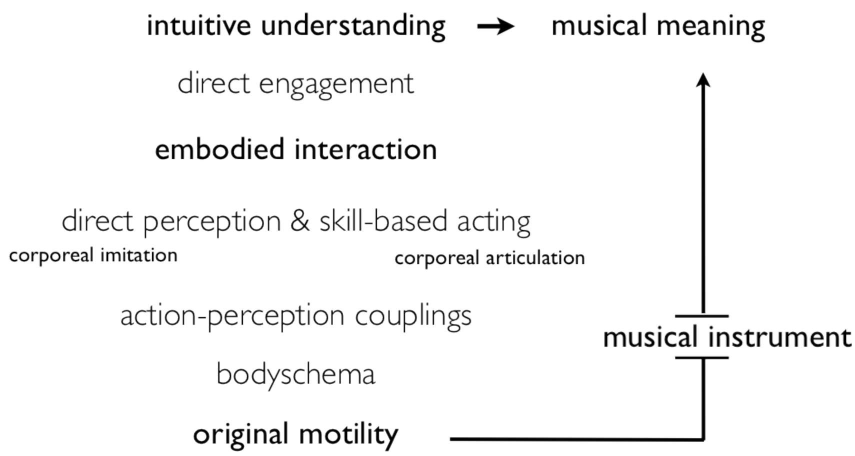


Figure 3.2. The musical instrument can block or allow the original motility, which is the condition of possibility to engage in an embodied interaction with the music and to attribute meaning to the music based on an intuitive understanding.

Incorporating the instrument and restoring the body in its original motility is a question of developing a new whole, a unity that is more than the mere sum of its parts. A viable conceptualization to explain the establishment of such a unity is the concept of *instrumental genesis* (Rabardel, 1995; Rabardel & Bourmaud, 2003; Trouche, 2004). This is a dialectic process that involves the transformation of the musical instrument from a mere material artefact or tool into an *instrument* or *functional organ*, i.e. a functionally integrated, goal-oriented configuration of internal (musician) and external (musical artefact) resources (Kaptelinin, 1996b). Throughout this process (see Chapter 7 for an in-depth description), the musician acquires the so-called *usage schemes* (Rabardel, 2002; Trouche, 2004), which are responsible for the integration of the instrument related movements in the coordination system of the musician's body and for the resulting intimate match between musician and instrument. The usage schemes are the building blocks of the so-called *instrument mediated action schemes*, which allow automatically triggering the adequate responses when focusing on the music.

Learning how to play a musical instrument involves both the acquisition and automation of these different schemes. Their automation might be coupled to skill-based playing and direct perception. When these schemes are automated they allow the automatic processing of information and the automatic generation of the adequate motor responses (Sweller, et al., 1998). As such it becomes possible to engage in an embodied interaction with the music (see also chapter 7).

To conclude, in this section it was argued that the involvement with music while performing has a firm corporeal basis that does not merely represent the movements necessary to play the instrument. To allow an embodied interaction with the music, musician and instrument must intimately match to such a degree that the musical instrument becomes a natural extension of the musician.

3.2.3. The multimodal nature of musical involvement

An important aspect of embodied music cognition is its multimodal nature. When being involved with music, the interaction with the musical context (musical instrument, music, teacher or audience, classroom or concert hall) involves the simultaneous perception of the different sensory modalities and a close interaction of sensory processing with motor production (Lappe, Herholz, Trainor, & Pantev, 2008). Within this multimodal interaction, one modality can, for instance, disambiguate information of another modality. This means that different modalities can provide means of calibration for one another and a percept from one modality can even override that of another modality (Ernst & Bülthoff, 2004; Meredith, 2002). According to Leman (2007) the unifying principle that links the mental processes to the multisensory experience of music is the process of corporeal intentionality (imitation and articulation) (see previous section).

Implications for music instruction

Following the theory of embodied music cognition, it is important that any form of music instruction acknowledges the body as a key component of musical meaning formation processes and musical understanding. This has several implications: on the role of the body, on the role of the instrument and on the multimodal nature of musical involvement.

Beyond the instrumentalist view of the body

Adopting an embodied approach to music instruction involves an approach to the body that goes beyond the instrumentalist view of the body as a tool that needs to be mastered in function of playing the instrument. Within the instrumentalist view, the role of the body becomes detached from the musical signification process because the meaning of the music is predefined by the teacher's model. Accordingly, the master-apprentice model of music instruction envisions a "docile" body that through templates of right posture and instrumental technique is deployed to reproduce the music according to a disembodied model of the music. That is, the model is not constructed by the learner on the basis of the subjective – corporeal – experience with the music but it is provided by the teacher in the form of propositional knowledge or by demonstration. This leads to "competent" performances that draw on conventional (e.g. determined by a certain school of playing) ways of moving, orienting and behaving.

In contrast to the instrumentalist view of the master-apprentice model, the embodied approach envisions a "motile" body that, in function of an attunement to the music, draws on its original motility (Merleau-Ponty, 1945) to perceive the elements of the music and attribute meaning to the music by constructing of an embodied model of the music. Here, the role of the body is constitutive to the musical signification process. Thus, musical understanding is embodied in the sense that it originates from feeling the music from within, that is, through the bodily sensing, feeling and experiencing of the musical sounds (Shepherd, 2002). It emphasizes the importance of the bodily experience of musical elements preceding the control of musical parameters.

Acknowledging this constitutive role of the body for the musical signification process urges music instruction to be learner-centered. This leaves the necessary space for the learners' autonomy in establishing a meaningful relationship with the music. After all, how the body finds it way into the music and resonates with it is determined by personal propensities and possibilities (Bowman, 2004). This has further implications on the use of the body, on the role of an embodied interaction with music and on the learners' experiential background.

Exploring music is also a question of exploring the body, preferably in conjunction with the musical instrument but also without. This means that learning and teaching are not only concerned with the technical perfection of sound-producing and sound-facilitating (supporting sound production) gestures but actively exploit the sound-accompanying (corporeal attunement to the music) and communicative gestures (Jensenius, Wanderley, Godoy, & Leman, 2010). Examples of exercises that exploit sound-accompanying gestures are given in figures 3.3 and 3.4. In the first example, movement is used to corporeally experience a phrase. Trying to fit the lateral body movement to the length of the phrase provides learners with a corporeal sense of the phrase's timing. In the second example, stepping with the feet is used to corporeally articulate the strong and weak beats of a four beat measure. Using these feet movements while playing a phrase provides learners with a corporeal sense of the arsis and thesis of a musical phrase.

Figure 3.3. A movement exercise to experience the timing of a phrase.

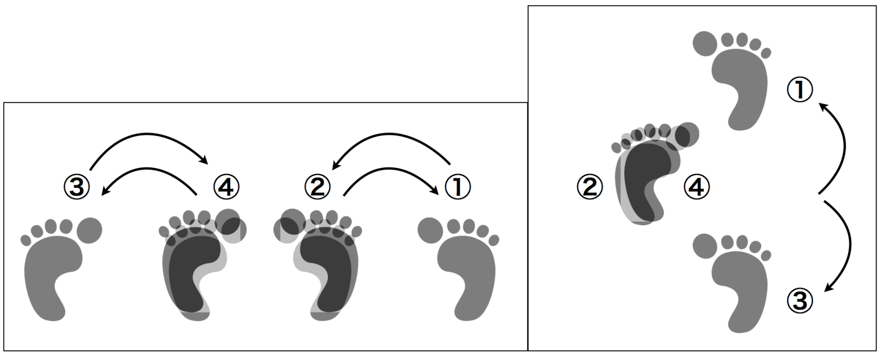


Figure 3.4. Stepping exercise to learn about strong and weak beats.

Indeed, one should be aware that the focus on technical skills and templates of right posture (docile body) can hinder the development of corporeal attunement to the music because the expressive gestures that follow from this attunement are blocked in favour of sound-producing gestures (Davidson & Correia, 2002). Therefore, acknowledging the importance of corporeal intentionality in order to develop an embodied understanding of music implies pursuing the integration of the different kinds of performance related gestures. This integration will establish a personal repertoire of movements that constitute a frame of reference for the musical signification process. This repertoire of musical movements is also influenced by the movement repertoire the learner has acquired before music instruction. Teachers often intuitively grasp this aspect of music learning and regularly refer to this repertoire in order to help the learner to develop sound-producing gestures (e.g. pianists who hold their hand as if holding an apple). However, we believe that the reference to this daily movement repertoire needs to go beyond technique and posture and must be expanded to the development of musical understanding and expressiveness.

In view of developing an embodied understanding of music, it is also vital for the learner to, from the early beginnings of learning how to play a musical instrument, engage in an embodied interaction with the presented musical content and establish a meaningful relationship with the music. That is, from the point of view of the learner, the musical content and learning how to play it must make sense. For example, according to Bamberger novices intuitively pay attention to structurally meaningful entities such as motives, figures and phrases, not to individual notes (Bamberger, 1996, 1999). This intuitive attending might be linked to the process of corporeal attunement to the music. During this process, meaning is extracted from the music by transferring musical patterns onto structures, patterns and gestures that originate from the learners' embodied existence. In other words, newly presented musical content must be translated to the learner's world of experience instead of being alienated from it. This might result in novices finding it much more easier to attune to musical patterns, motives and even phrases (e.g. from a familiar song).

Therefore, adopting an embodied approach to music instruction also means valuing the learners' background, interests, intentions, expectations and beliefs. They constitute the embodied repertoire of meaningful elements (e.g. gestures, thoughts) to which elements of the music are mapped in order to make sense of the music. Responding to these elements might stimulate the learners' signification process.

Beyond the instrumentalist view of the musical instrument

Adopting an embodied approach to music instruction also involves adopting an approach to the musical instrument that no longer adheres to an instrumentalist view. It acknowledges the view that not only the body but also the instrument is constitutive to musical meaning. This implies an instructional approach in which the focus on mastering the instrument in function of a pre-defined model of the music is replaced by a focus on pursuing an intimate relationship between musician and musical instrument that eventually leads to the merging of the two.

The musical instrument is not something that needs to be mastered but something that needs to be touched and felt (Rebelo, 2006). Wagman & Carello

(Wagman & Carello, 2001) refer to *dynamic touch*, i.e. the manipulation of an object by means of muscular effort, as a way to discover the properties of a tool and to regulate the manipulation of the tool in function of a certain goal. Just like a baby discovers its body and the possibilities to interact with its environment through the process of body babbling (Clark, 2007), the novice who learns to play a musical instrument can discover the possibilities, or affordances, of the instrument (Pederiva & Galvão, 2005). And eventually, like the body does, the instrument can become 'transparent equipment', a tool whose use and functioning have become so natural that there is a very real sense of having merged. Therefore exploring the instrument, experimenting with its possibilities and improvising are musical activities that support an embodied approach to instrumental music instruction. They allow moving from the sensorimotor coupling during trial and error towards the construction and automation of the necessary mental schemes, i.e. the specialized subsystems that realize a tight action-perception coupling (Pezzulo & Castelfranchi, 2007). Due to the goal-directed and context-based nature of such schemes (Pezzulo, 2007), it is important to couple the explorations and experimentations to musical – expressive – goals. In this way, even learning how to play a simple long note has an expressive connotation. Instrumental music instruction then is no longer based on a linear view on technique and musical expressiveness.

A multimodal approach

Finally, adopting an embodied approach to music instruction also concerns the multimodal nature of musical involvement and its connection to musicianship. In our view, exploiting the multimodal nature of musical involvement contributes to the development of musicianship, which is about developing the dispositions and abilities that allow the musically informed perception and production of music. The corporeal dimension that is developed through playing is the basis for musicianship (Bowman, 2004; Elliott, 1995). However, limiting musical development to this dimension, as in a technically oriented instruction, leads to musicianship in a narrow, specialized, sense. In order to develop genuine – embodied – musicianship it is necessary to look beyond the corporeal dimension of instrumental competence and craftsmanship and to develop the ability to draw upon corporeal resources outside the purely instrumental domain (Bowman, 2004). This will result in moving from the conventional (docile) ways of moving to more imaginative (motile) ways of moving musically.

A possible way for instrumental music instruction to appeal to the multimodal nature of musical involvement and understanding and to connect to resources outside the "purely" musical domain is through the integration of activities that deploy the different sensory modalities. One example of such an activity is the integration of different movements to appeal to the kinaesthetic dimension. Research has shown that movement influences the perception of music (e.g. Naveda & Leman, 2009; Phillips-Silver & Trainor, 2005). Another example is drawing to music. This activity allows learners to express their experience and understanding of the music in the visual modality. Research has shown that this supports the musical signification process (Barrett, 1997; Blair, 2008; Reybrouck, Verschaffel, & Lauwerier, 2009).

These kinds of activities stimulate the musical signification process by appealing to different sensory modalities. However, they are not common in instrumental practice and therefore assume an important rethinking of curriculum.

To sum up, the embodied cognition paradigm perfectly joins constructivism in its emphasis on the learner's experience and active role in the process of constructing meaning. At the same time it complements constructivism by elaborating the key role of the body in the musical signification process. Acknowledging the importance of developing an embodied musicianship urges an approach to instrumental music instruction in which, inter alia:

- *the bodily experience of musical elements precedes the control of musical parameters.*
- *the musical instrument is considered as constitutive to the musical signification process.*
- *exploration with the body and the instrument are use to develop musical understanding and meaning making.*
- *the learners' embodied repertoire of meaningful experiences is valued and addressed.*
- *a diversity of activities are used to appeal to the different senses to develop musical understanding.*
- *playing by ear precedes playing by notation.*

PART 2: TECHNOLOGICAL FRAMEWORK

CHAPTER 4

The potential contribution of technology

Anno 2012, both constructivism and embodied music cognition are undeniably connected to technology. While the former acknowledges the potential of technology to support and create learning environments that foster the active role of the learner, the latter acknowledges that technology can be used as a monitoring instrument for musical involvement or as a tool for an embodied form of music making. In this chapter the link between both frameworks and technology is elaborated upon (section 4.2. and 4.3.). But first, we will give a brief overview of currently developed applications used for instrumental music instruction (section 4.1.).

4.1. Technologies for instrumental music teaching and learning

From the literature overviews by Webster (2002, 2011b) and other scholars (e.g. Frankel, 2010) as well as from a growing number of books devoted to technology in music education (Finney & Burnard, 2009; e.g. Manzo, 2011; Rudolph, 2005; Watson, 2011), it becomes clear that computers and computer-based applications are playing an increasingly important role in the field of music education. Both software and hardware developments have led to numerous explorations and implementations within the music curriculum.

This section will not repeat such an overview of the range of technology applications and their use in the broad spectrum of music educational systems. It will rather be limited to a non-exhaustive overview of currently existing educational technologies that focus on instrumental (incl. singing) music teaching and learning. The aim of this overview is twofold: showing what kind of visual feedback these systems provide the learners with and to what extend empirical studies have been undertaken. The different systems are organized into, possibly overlapping, categories. Table 4.1 gives an overview of these categories and systems.

Table 4.1. An overview of different categories of interactive music systems for instrumental music teaching and learning.

Category	Educational technologies
Monitoring musical parameters	Winsigad – Sing & See™ – Voce Vista – InTune – MEAWS – drum-loop-performance – Seeing sound
Monitoring musical expressiveness	PianoForte - Mixtract
Monitoring body movement	AMIR – MusicJacket – Syssomo – Elbow Piano
Intelligent tutoring	PianoTutor – IMUTUS – VEMUS – Digital Violin Tutor
Improvisation	Virtual Musical Environment – MIMI
Musical Games	Hedgehog – Pitch controlled pong

4.1.1. Monitoring musical parameters

A first category of technological applications aims at the real-time monitoring of the different parameters of the music played by the learner.

Several applications aim at monitoring pitch accuracy, especially within vocal performance instruction. The VOXed project developed *Winsingad*, an application that aimed at complementing vocal instruction with visual feedback (Howard, et al., 2007; Welch, Himonides, Howard, & Brereton, 2004). It offers a sound wave form against time, a representation of the fundamental frequency against time, a short-term spectrum, a narrow band spectrum, the spectral ratio against time, a visualization of the vocal tract area and a mean/min vocal tract area against time (see Figure 4.1). Each parameter appears in a separate panel that can be moved around vertically and enlarged into a greater screen space. In addition, a web camera window can be displayed to show the singer's position. Two teachers tested the system, giving vocal instruction to two students with and to two students without the help of Winsingad. The methodology of the experiment was very interesting because it compared teaching with and without the technology based on a systematic observation (Welch, Howard, Himonides, & Brereton, 2005).

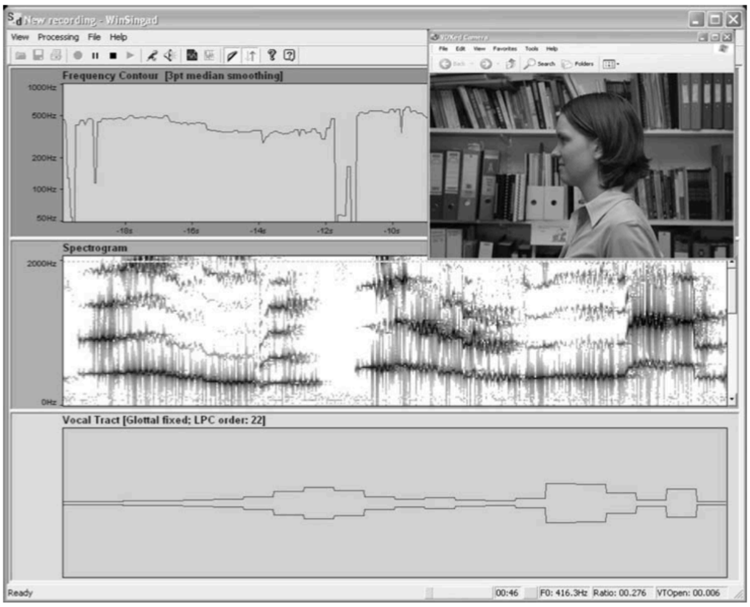


Figure 4.1. The visual feedback provided by Winsigad. In this figure, feedback is given on pitch (top), timbre (middle) and dynamics (bottom) (Welch, et al., 2005).

A similar application is the commercially available *Sing & See™*. It uses real-time spectral displays, metering and traditional notation to provide singers with visual feedback on their vocal performance. The system has a variety of displays that show different aspects of the voice (see Figure 4.2). Pitch is displayed on a keyboard, as a continuously moving line and on a musical stave. Furthermore, the harmonics of the sound are shown on a colour spectrogram. Finally, a level meter is shown to provide information on the loudness of the singing voice. The system was tested with forty-five participants (Wilson, Lee, Callaghan, & Thorpe, 2008; Wilson, Thorpe, & Callaghan, 2005). The experiment followed a baseline-intervention-post-test between-groups design. Each participant received a single one-hour instruction that was conducted by the researcher, a trained and experienced singing teacher. The overall procedure consisted of a pre-session questionnaire, a singing lesson (including pre-test, intervention and post-test measurements), and a post-session questionnaire.

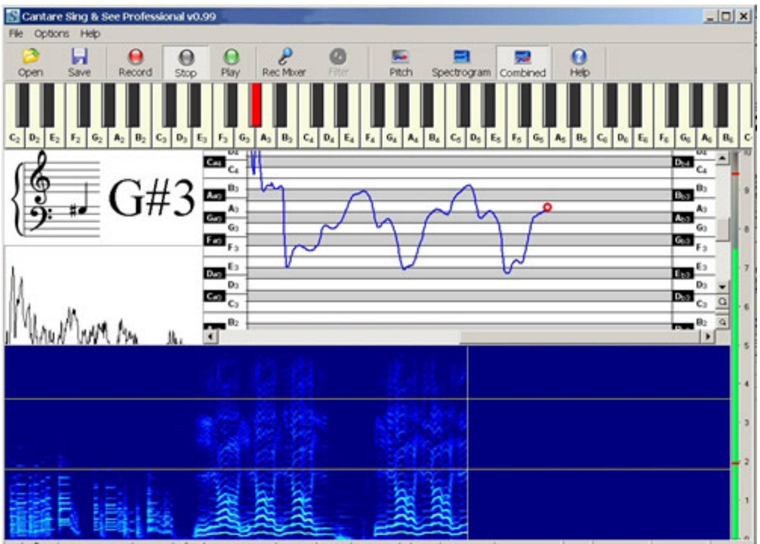


Figure 4.2. The visual feedback of Sing and See: pitch on a musical stave (left middle), as a point in a continuous line that represents the melodic contour (right middle), and on a piano keyboard (top). Additionally, the system provides a spectrogram display (bottom) (Wilson, et al., 2008; Wilson, et al., 2005).

Another singing application is *Voce Vista* (www.vocevista.com). This system provides detailed information on the acoustic waveform, the spectrum and the spectrogram of an 8 seconds during vocal performance (see Figure 4.3). By using an electrolaryngograph or electroglottograph it has the ability to observe the inter-relationship between the excitation and the acoustic output within each cycle of vocal fold vibration. An initial series of measurements was made on seven singer. We found no literature on educational experiments.

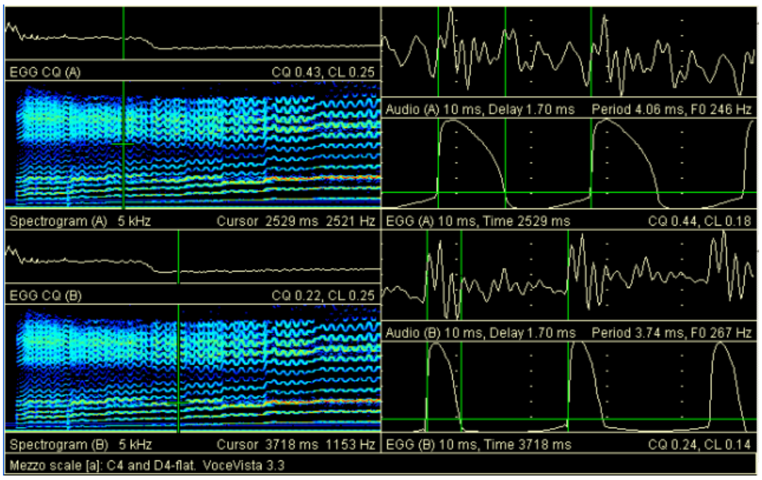


Figure 4.3. The visual feedback of Voce Vista, showing the waveform of the electroglottographit (EGG) and a spectrogram of the sound. A cursor (green line) can be placed at any point in its duration for detailed analysis of the moment (http://www.vocevista.com).

An application that resembles the singing applications is *InTune* (K. A. Lim & Raphael, 2009). This application is designed to help musicians hear better and improve their intonation. Based on the score following, it provides learners with a marked-up representation of the score, a piano roll like pitch trace and a spectrogram (see Figure 4.4). A small 20-subject user study was performed, using undergraduate and graduate performance majors from the School of Music (K. A. Lim & Raphael, 2010). Participants chose and performed an excerpt from 10 ready-made pieces in *InTune*, while the program recorded their performance. Recordings were played and participants were asked to evaluate their own performance with regard to pitch, followed by a comparison with the systems evaluation. Finally participants completed a questionnaire on the perceive usefulness of the system.

Figure 4.4. The three displays of InTune: a score image (top) with coloured heads of “suspicious” notes, a pitch trace (bottom left) showing precise pitch evolving over time, and the spectrogram (bottom right) showing frequency content evolving over time (K. A. Lim & Raphael, 2009).

MEAWS, or: Musician Evaluation and Audition for Winds and Strings, is a software tool to support technical exercises when learning how to play a musical instrument (Percival, Wang, & Tzanetakis, 2007; Robine, Percival, & Lagrange, 2007). It provides a number of tests related to intonation, rhythm, or steady loudness (see Figure 4.5). Learners (or the teacher) may select a particular test, do the exercise, and then receive a grade. The system was tested on the basis of a qualitative study with four musicians, who commented on the system via an anonymous web form.

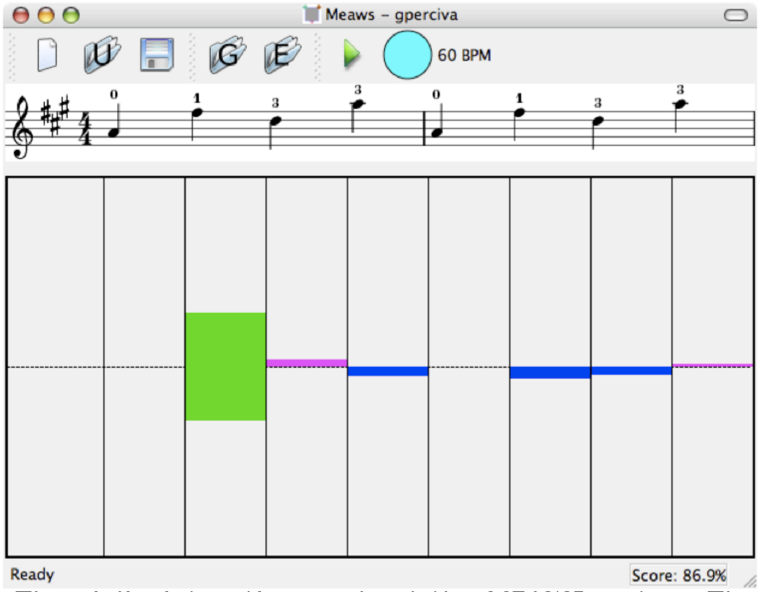


Figure 4.5. The violin intonation mode of the MEAWS system. The colour and direction of the bars indicates the type of error made: a lower blue box means that the user played too flat, an upper magenta box means that the user played too high, while a green box in both directions indicates that intonation was inconsistent. The size of the box indicates the extent of the error (Iwami & Miura, 2007).

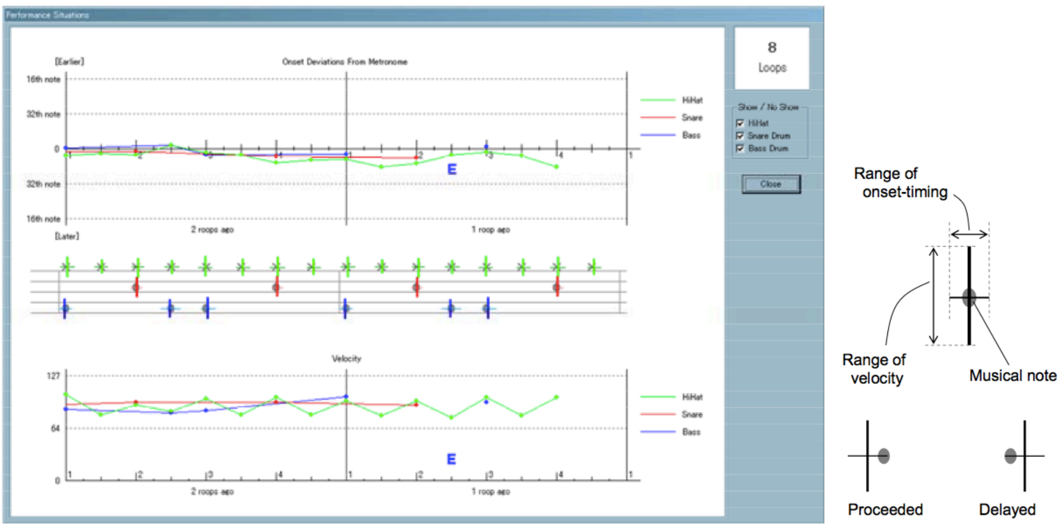


Figure 4.6. A screen capture of the drum-loop performance system of Iwami and Miura (2007).

Some applications focus on rhythm accuracy. For example, Iwami and Miura (2007) propose a system that can be used to help drummers to practice a technique called here 'drum-loop performance' (DLP)", i.e. repeating basic rhythm patterns that consist of one or two measures under given tempi, using a MIDI drums (see Figure 4.6). The system was used with "several amateur drummers" (sic) whose performance of a given score was analyzed.

Next, some applications aim at monitoring tone quality or timbre. One such an example is the *Seeing sound* system (Ferguson, 2006). The application presents multiple streams of data, related to pitch, loudness, harmonic content and noisiness, in a single display (see Figure 4.7). We are not aware of any empirical research on the use of the Seeing Sound system.

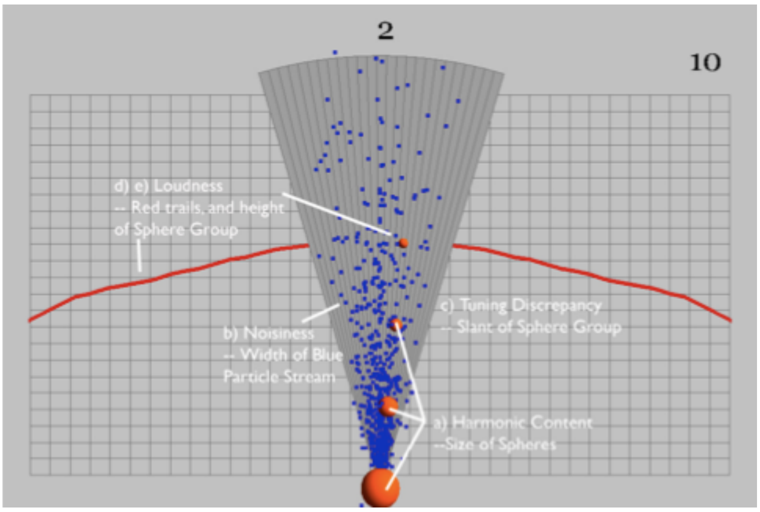


Figure 4.7. The visual display of the “Seeing sound” – system. Sounds with harmonic content containing a strong fundamental frequency are displayed as a large sphere with smaller spheres above it (a). A ‘fountain’ of particles, which are shown directly behind the spheres, represent the noisiness of the sound (b).Loudness of the sound is represented by the red line and the height of the sphere group (d) (Ferguson, 2006).

Worthwhile mentioning is Ferguson’s monitoring system based on sonification, which serves as an alternative to interactive visualization methods (Ferguson, 2006). The system aims at providing information on accurate pitch, note onset, tone loudness, rhythm accuracy, and articulation. We are not aware of any experiments with the system.

4.1.2. Monitoring musical expressiveness

While many applications focus on sound characteristics, some applications focus on expression. One example of such an application is *PianoFORTE* (see Figure 4.8). This system wants to bridge the gap between simply playing the notes and a genuine performance by helping the teacher communicating “the distinction between the art of playing piano and the technique of playing the correct notes” (Smoliar, Waterworth, & Kellock, 1995). Smoliar and colleagues mention plans to test the usability of the system but we could not find any further literature on these tests.

Figure 4.8. Piano Forte's visual representation of the score, which is augmented with triangular marks that provide information on articulation (e.g. note onset, weight) (Smoliar, et al., 1995).

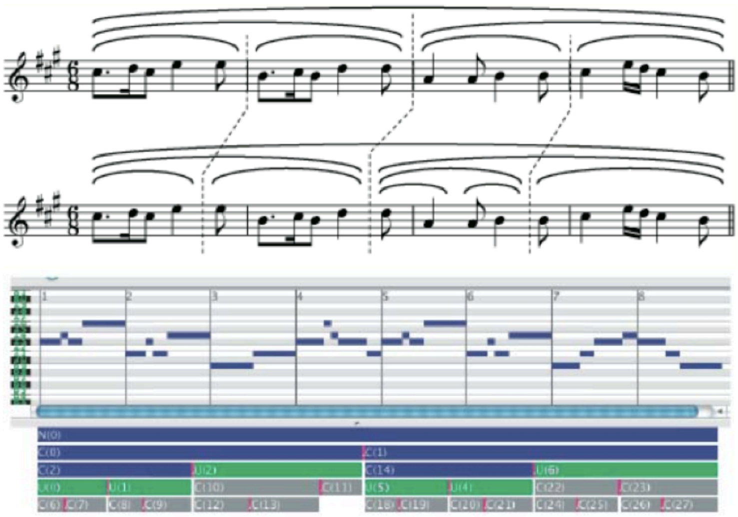


Figure 4.9. The Mixtract display on phrase structure. Green boxes indicate user-specified phrases, while blue and gray boxes represent the system-analyzed hierarchical phrases based on the user's phrases. Red lines indicate phrase boundary candidates calculated by the system (Hashida, Tanaka, & Katayose, 2009).

Another application that monitors student performance's expressiveness is MIXTRACT (Hashida, et al., 2009). It provides musicians with a function for assisting in the analysis of phrase structure and a function to show the degree of importance of each note in a phrase group. The system integrates a performance design GUI using expression curves for each phrase and an editor for the start timing, duration and dynamics of each note (see Figure 4.9). A one-time workshop was organized to evaluate the system. Seven students participated and comments were collected in an informal way (Hashida, et al., 2009).

A final example of an application that focuses on musical expressiveness is PracticeSpace (Brandmeyer, Hoppe, Sadakata, et al., 2006). When using PracticeSpace, the teacher selects or performs a certain musical passage, which is displayed in real-time on the student's screen. The visual feedback consists of geometric shapes that are mapped to aspects of the playing (e.g. voice, timing, velocity). The student tries to imitate the teacher's model. Aspects of the student's playing are in real-time displayed on top of the teacher's visual model. As such, discrepancies between the teacher's and the student's performance are visually represented. A study was conducted to investigate the effect of low-level vs. high-level visual feedback (Brandmeyer, et al., 2006). Eighteen conservatory level percussionists performed imitations of different models while receiving either low-level feedback on the timing and dynamics of their performance or high-level feedback on the expressive style of their performance (see Figure 4.10).

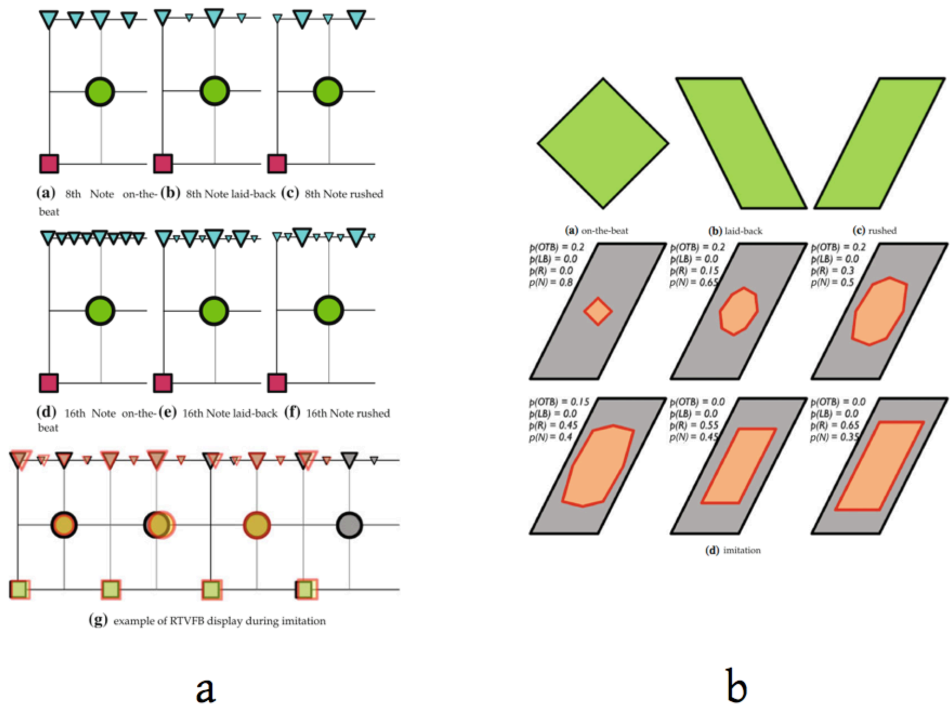


Figure 4.10. PracticeSpace used two kinds of feedback: low-level visual feedback on timing and dynamics (a), and high-level visual feedback on the expressive style of performing (b).

4.1.3. Monitoring body movement

A growing number of applications aim at monitoring bodily aspects of learning how to play an instrument.

AMIR is a visual and auditory display that can be used in string instrument training (Larkin, Koerselman, Ong, & Ng, 2008; Ng, et al., 2007). The system is based on the 3D motion analysis of movements while playing an augmented violin. It uses several sonifications and visualizations to provide both real-time and off-line feedback about bowing technique (see Figure 4.11). The sonifications were discussed with string teachers and students and tested with six university-level music performance students (Larkin, et al., 2008).

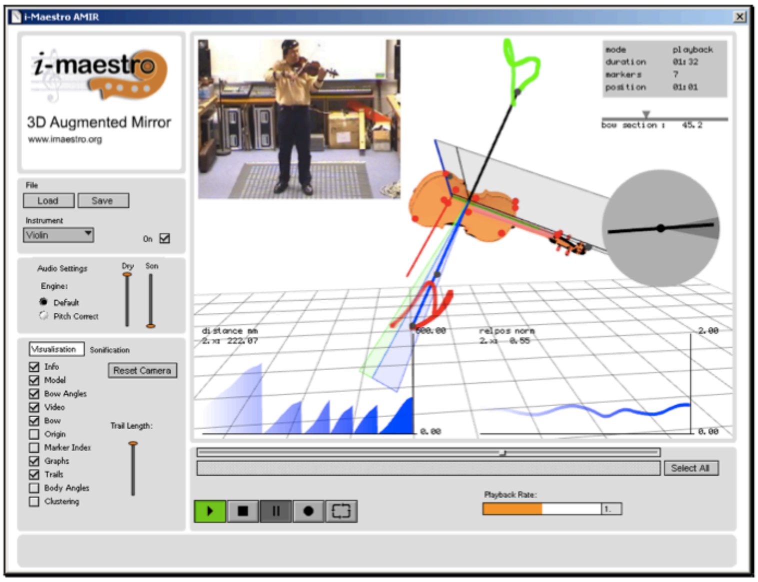


Figure 4.11. Visual display of the I-Maestro AMIR system, providing information on a bowing gesture (Larkin, et al., 2008).

MusicJacket is a wearable system that gives vibrotactile feedback (see Figure 4.12) to the arms in order to indicate how to correctly hold the violin and how to bow in a straight manner (Johnson, van der Linden, & Rogers, 2010). An initial study with this system involved four participants. First they received a 40-minute lesson on how to hold the violin and the bow, without wearing the MusicJacket. Then, they practiced with the MusicJacket during two sessions, each for about 30 minutes. At the end of the second practice session they were requested to play the exercises without receiving any feedback while being observed by experienced violinists. Participants were also requested to informally comment on their experience. In another study, eight novice violinists (without prior experience of violin playing) were studied (van der Linden, Schoonderwaldt, Bird, & Johnson, 2011). The participants were divided into a feedback group (receiving vibrotactile feedback) and a control group. Six training sessions were organized during a period of eight days. Rhythmic exercises were designed in order to stimulate the use different parts of the bow and were all played on the same open D string. Furthermore, an "in the wild" study was conducted over two months with two teachers and ten children (Van Der Linden, Johnson, Bird, Rogers, & Schoonderwaldt, 2011). Each teacher provided five students with instruction with the support of the MusicJacket system. This resulted in approximately fifty lessons. Data were collected by means of interviews, informal conversations and the logging system of MusicJacket.

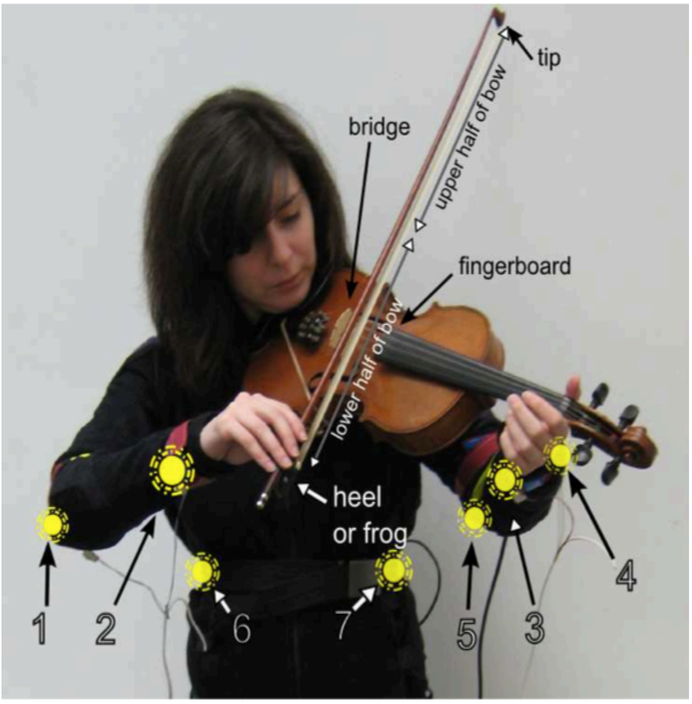


Figure 4.12. A violinist equipped with the *MusicJacket*. The system uses seven vibration motors, positioned on the right arm (1 & 2), the left hand (3 & 4), on the left arm (5) and on the ribs (6 & 7) (Johnson, et al., 2010).

Syssomo is a system that visualizes the arm movements of pianist, using a custom built sensing platform, MotionNet (Hadjakos, Aitenbichler, & Mühlhäuser, 2008). Based on score following, the system synchronizes two performances of the same piece in order to overlay motion data, MIDI (piano roll), and video (see Figure 4.13). This way, the user can easily compare the differences between the performances of a teacher and a student. We found no information on experiments with the system.

Elbow piano tracks the pianists' elbow movements with a goniometer (Hadjakos, Aitenbichler, & Mühlhäuser, 2008b). The system provides feedback by the sonification of two types of piano touch: with and without movement in the elbow. Four pianists (professional level), one composer (advanced level), and one singer (intermediate level) participated in an evaluation study. They played pieces of her/his own choice with the Elbow Piano and, afterwards, completed a 5-question questionnaire and were interviewed.

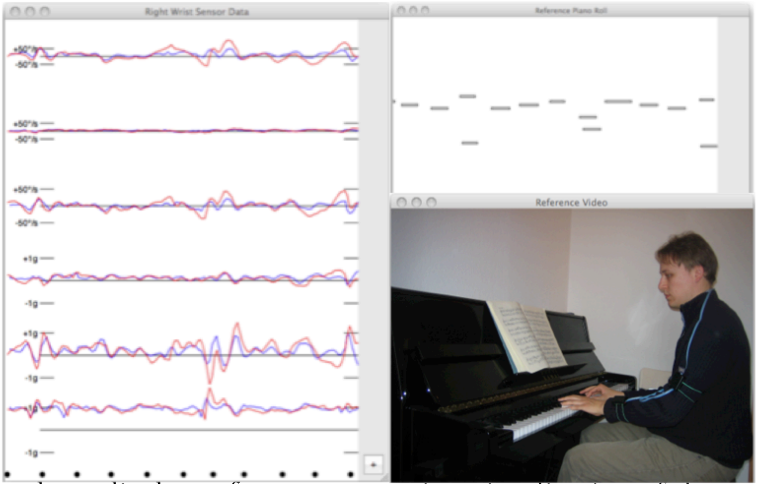


Figure 4.13. Three displays of Syssomo: Motion visualization of the gyroscope and accelerometer data (left), a piano roll (top right) and a video of the player (Hadjakos, Aitenbichler, & Mühlhäuser, 2008a).

4.1.4. Intelligent tutoring systems

PianoTUTOR is an intelligent tutoring system to help beginning piano students by correcting their mistakes before these become ingrained through practice and by teaching new material as soon as the student is ready (Dannenberg, et al., 1990; Dannenberg, et al., 1993). The systems integrates real-time score-following, a graphical display allowing multi-media presentations to the students, a video player to provide feedback on the playing (see Figure 4.13), a lesson database and an expert system that delivers the chosen lesson, provides instruction, evaluates student performances, and selects remedial lessons if necessary. The system was tested in an informal way with ten students.

Figure 4.13. The PianoTutor system.

Another intelligent tutoring system is *IMUTUS* (Schoonderwaldt, Hansen, & Askenfeld, 2004). It provides a practice environment for recorder and integrates a music recognizer, a score follower and matcher, an automatic performance evaluation module and a score viewer (see Figure 4.14). The system was tested by 6 students for three weeks (Raptis, et al., 2005).

Figure 4.14. The Imutus interface provides a score with feedback (e.g. highlighted note with arrow), a help function that provides extra verbal feedback (frame above the score, in the middle), different buttons (e.g. to play the music, to get extra help) and a grading (stars on the right above the score) (Raptis, et al., 2005).

A third system, *VEMUS*, continued the work on the *PianoTUTOR* and *IMUTUS*. It is an open music tuition framework for popular wind instruments such as the flute, the saxophone, the clarinet and the recorder that address students of beginning to intermediate level (Fober, et al., 2007). The system targets improvement at the instrument practice level by providing automatic performance evaluation in the form of visual and aural feedback (see Figure 4.16).

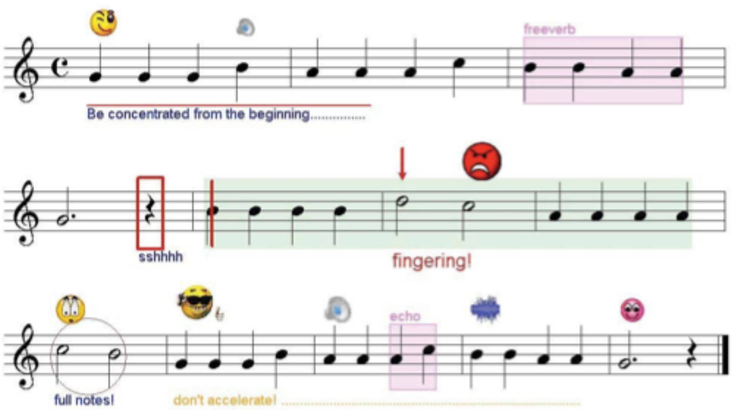


Figure 4.15. The Vemus annotated score (Fober, et al., 2007).

VEMUS also wants to complement classroom instruction by supporting teaching and by promoting collaborative learning and group activities. Evaluation in different European countries has focused on the quality of the student performances and on the student's motivation in devoting more time to practicing.

Another system worthwhile mentioning is the *Digital Violin Tutor* (Yin, et al., 2005). This intelligent tutor system wants to help students tune the violin, to point out performance mistakes, and to demonstrate the correct way of playing. It integrates a tuner, a transcriber to transform the audio input from the student's play into a note table, an automatic performance evaluator that compares the transcribed notes with either the score or transcribed teacher's play, and a an animator that demonstrates the correct playing (see Figure 4.16). The application was tested in a one-time experience by twelve violin players (5 novices, 3 parents, 2 conservatory students and one teacher) and evaluated with a questionnaire on usability, usefulness, and possible improvements.

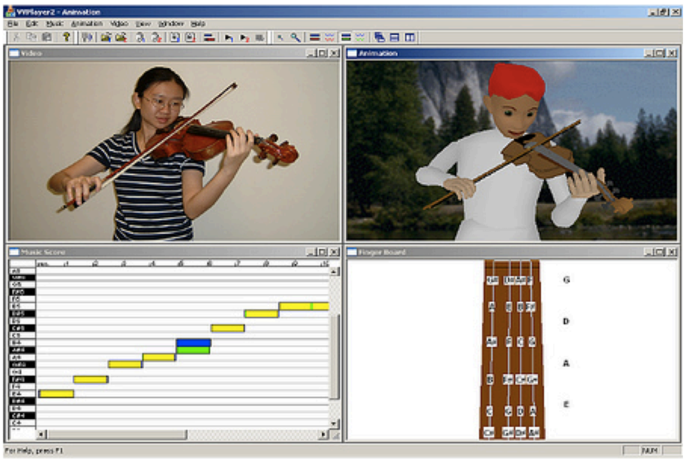


Figure 4.16. Digital Violin Tutor, showing the learner (top left), a model (top right), a piano roll (bottom left) and a representation of the strings with the different positions (Yin, Wang, & Hsu, 2005).

4.1.4. Improvisation

Some applications aim at developing improvisation skills. The work of Addessi, Pachet and colleagues is such an example. Continuing on the work done with the Continuator (Ferrari, Addessi, & Pachet, 2006; F. Pachet, 2002), the Mirror project (Addessi & Volpe, 2011) aims at creating a novel form of pedagogical software for improvisation that particularly could be used in the context of musical education for young children. The Miror Impro is designed to respond in a varied but stylistically consistent manner to the child's playing. It introduces a feedback loop to the music production process in order to establish a question-answer interaction protocol (Pachet, 2006). The Miror Project involves both psychological and pedagogical experiments currently ongoing. These experiments built upon a number of experiments with the Continuator (e.g. Addessi & Pachet, 2005; Addessi, Pachet, & Caterina, 2004; F Pachet, 2002a, 2002b; Pachet, 2006).

Another application that supports learning how to improvise is the Virtual Musical Environment (VME), developed by Johnston and colleagues (Johnston, et al., 2005). The system aims at encouraging a creative and playful approach to music and skill development by creating a 'virtual world' in which the musician can navigate by playing on a MIDI or acoustical instrument. Based on pitch and loudness, a cursor can be moved to different locations on the screen to activate particular behaviours of the system (see Figure 4.17). A professional musician "with extensive performing credits" performed a preliminary evaluation. We are not aware of empirical tests done with the system.

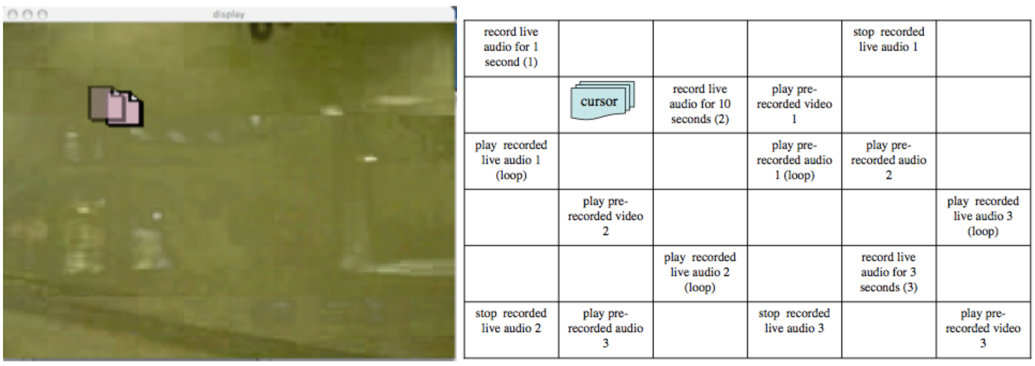


Figure 4.17. The VME systems allows to navigate in a virtual world (left) by playing. Based on pitch and loudness a cursor moves on the screen and thereby activates different tasks (right) (Johnston, Amitani, & Edmonds, 2005).

A third example is MIMI, a multi-modal interactive musical improvisation system (Schankler, Smith, François, & Chew, 2011). The system is factor-oracle based, i.e. an efficient data structure that models the recombination of musical segments using an online construction algorithm and a stochastic traversal algorithm. It also uses real-time visualization (see Figure 4.18) to help the performer at the piano keyboard plan and orchestrate improvisation.

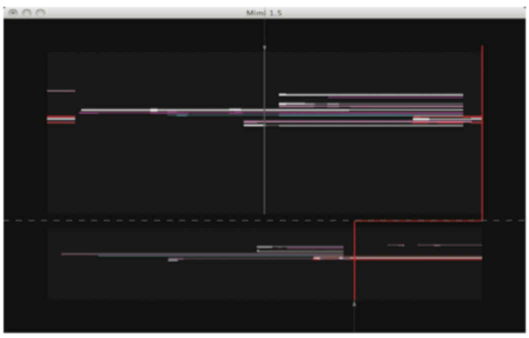


Figure 4.18. The real-time visualization of MIMI (Schankler, et al., 2011).

4.1.4. Musical games

A last category of applications consists of musical games. Two examples are the "Hedgehog" game (see Figure 4.19) and the pitch-controlled pong (see Figure 4.20) aim at learning to sing in tune by using the voice for a pitch-based real-time control of position on the screen (Hämäläinen, Mäki-Patola, Pulkki, & Airas, 2004). The Hedgehog game was tested informally with 6 third-graders, 3 pre-schoolers and 2 14-year olds.

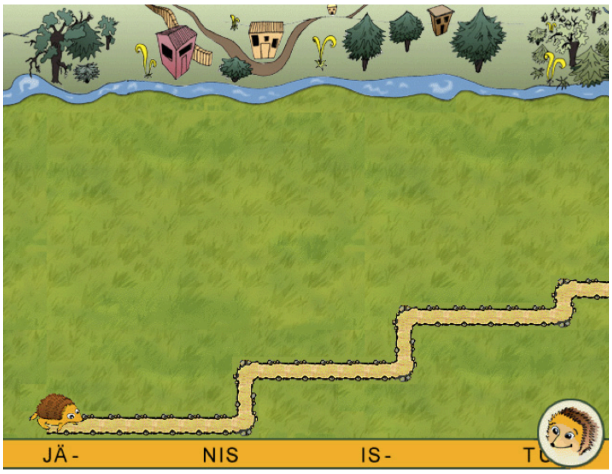


Figure 4.19. A screenshot of the hedgehog game in which the vertical position of the hedgehog is controlled by the pitch of a user's voice. To keep the hedgehog on the pad, it is necessary to sing the song correctly. The words of the song are shown at the bottom of the screen (Hämäläinen, et al., 2004).

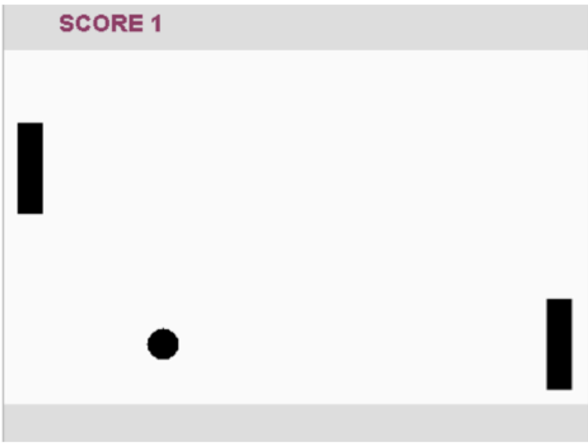


Figure 4.20. A pitch-controlled Pong game. The bat on the left moves according to the pitch of a user's voice. The bat on the right is computer controlled (Hämäläinen, et al., 2004).

In this overview it was shown that the development of interactive music systems for instrumental music instruction is expanding. The evaluation and experimental results often point at the potential benefit of using such systems to teach or learn how to play a musical instrument. However, it is shown in this overview that only a limited number of empirical studies with the systems are done. Exceptions are the studies with the Continuator and MusicJacket, and in projects such as the Miror project and the Vemus project. Also the study reported by Welch et al (Welch, et al., 2005) can be considered as an exception, based on the microanalysis that was performed.

Most systems are interactive on the basis of real-time feedback, whether visual, auditory or tactile. Visual feedback is mostly iconic or symbolic. Some systems use traditional score, but the overview clearly shows a tendency to depart from a purely score-based approach. An important rationale behind the design is the systems' ability to monitor performance and to provide knowledge of results or knowledge of performance. Other systems focus on improvisation, expressiveness and games.

The following sections elaborate on the ways in which interactive music systems can contribute to a change in focus from a more traditionalist approach to an embodied constructivist approach to instrumental music instruction.

4.2. Interactive music systems and constructivism

Interactive music systems constitute a specific learning environment in which the learner can actively participate and interact with music. As such they have the potential to promote and contribute to a constructivist approach to music teaching and learning.

4.2.1. Constructing knowledge: the role of visual feedback

Educational technologies, such as interactive music systems, are designed to promote learning. A basic feature of most of these applications is the use of visual feedback.

Interactive music systems that use of visual feedback have the potential to significantly contribute to learning and skill development. Providing this visual feedback might affect how new information is processed and how knowledge is constructed. The mechanism that underlies the construction of knowledge is the acquisition and automation of schemas (Paas, Renkl, & Sweller, 2003; Sweller, et al., 1998). These schemas provide a context for novel information (Chandler, 2005). According to Pezzulo (Pezzulo, 2007) schemas have four main properties: goal-orientedness, flexibility, selectivity and excitability. Adding visual feedback to the learning process might affect the construction of schemas because it has an impact on these properties.

Impact on the goal-orientedness of schemas

First, visual feedback might have an impact on the *goal-orientedness* of a schema by supporting the establishment of the internal models that mediate action and perception. Schemas are composed of inverse and forward models (Pezzulo, 2011). The former concern action control, the latter concern the prediction of sensory effects based on that control. These inner models provide an internalization of relevant characteristics of the learner-environment engagement by generating an internal loop that parallels actual sensorimotor interaction. This way, action effects can be predicted and actual effects can be compared to the predictive model, allowing the learner to monitor whether intentions are successfully enacted. Because the visual feedback of interactive music systems is based on objective measurement of the learners actions (e.g. bowing) or of the outcome of these actions (e.g. loudness) and because this visual feedback is not subject to the same processes as auditory feedback (Paivio, 2007), it can bypass perceptual difficulties related to auditory feedback (Thorpe, 2002). This is related to the modality principle of cognitive theory of multimedia learning, according to which presenting learning content in different modalities (e.g. auditory and visual) helps learners to more effectively process this content (de Jong, 2010; Sweller, et al., 1998). The visual feedback helps building *referential connections,* i.e. connections that integrate stimuli in different sensory modalities (e.g. visual and auditory) with one another and with relevant prior knowledge. According to Mayer and colleagues (1999) this is essential to constructivist learning.

Impact on the selectivity of schemas

Second, visual feedback might have an impact on the *selectivity* of schemas by drawing attention to specific information. Schemas are a way of coping with the complexity of information. They are specialized subsystems that realize a tight coupling between action and perception. When a schema is operating, it selects information, directs attention and uses only the goal-related stimuli. Accordingly the action-perception loop can both trigger actions or gather relevant stimuli. Adding visual feedback to the learning environment creates new stimuli that can become part of the schema-defined set of relevant stimuli. In other words, visual feedback might affect the realization and consolidation of these couplings.

Impact on the flexibility of schemas

Third, visual feedback might have an impact on the *flexibility* of schemes by influencing the choice, timing or order of actions according to the learning condition. Every action implies a set of perceptual and motor schemes that are hierarchically structured. Due to this hierarchical structure, schemes allow the realization of a goal in different ways (Pezzulo, 2011). Depending on variable contingent conditions (e.g. acoustics of a room), schemes can exploit a repertoire of actions (e.g. slur or detach a tonal pattern) (Pezzulo, 2007). Interactive music systems shape a condition and provide visual feedback on the failure or success of an action. Therefore, they inform on the appropriateness of a scheme. As such, the use of visual feedback when learning how to play an instrument might influence the hierarchical structure of schemes.

Impact on the excitability of schemas

Fourth, visual feedback might have an impact on the *excitability* or activity level of schemes by influencing the desirability and achievability of a schema. Schemes compete to be activated and the higher the level of activation, the higher the chance to be selected (Pezzulo, 2011). The activation of a schema depends on its desirability, i.e. the degree to which its goal suits current motivations (e.g. play technically or play expressively) and on its achievability, i.e. the degree to which it is expected to be successful. The visualization of interactive music systems can provide strong feedback on the achievability of a schema. An important aspect of schema activity is that an active schema (e.g. perceptual) can input other schemas (e.g. motor schema) and thereby regulate schema sequences.

And yet, despite the potential contribution of visual feedback to knowledge construction, it has been shown that it can have a degrading effect on learning as well, following the possible introduction of extra cognitive load or by the stimulation of an internal focus of attention. Furthermore, it has been shown that the use of visual feedback may lead to a dependency on the feedback, resulting in a detoriated performance when the visual feedback is removed.

Cognitive load

Visual feedback possibly introduces extra cognitive load because it can make the information that reaches a learner more complex (e.g. Sadakata, Hoppe, Brandmeyer, Timmers, & Desain, 2008; Thorpe, 2002). While already dealing with the auditory (result of playing), kinaesthetic (playing) and visual (e.g. score), additional information needs to be processed. This might increase the *intrinsic* (load placed on the learner by the nature of the materials being learned) and even *extraneous* (load that is unnecessary) cognitive load of the learning content. Consequently, *germane* cognitive load (required by the methods used for presenting new knowledge to a learner) is reduced at the expense of genuine learning, i.e. the construction of mental schemes (Paas, et al., 2003). Different studies on the frequent use of (visual) feedback have pointed out a possible decrease in learning (e.g. R. A. Schmidt & Wulf, 1997; Winstein & Schmidt, 1990).

For these reasons, it is important that the visual feedback that is provided by an interactive music system satisfies Bruner's instructional *principle of economy*, stating that the amount of information that must be held in mind and processed to achieve comprehension needs to be reduced (Bruner, 1960, 1966). The visual feedback must be easy to interpret (Elby, 2000; Thorpe, 2002). In this case the visual feedback might possibly be processed in the dorsal stream, a pathway of the visual cortex that mediates visually guided motor movements (Goodale & Milner, 1992). As such it may contribute to the integration of action and perception (Zatorre, Chen, & Penhune, 2007). Because in this case visual information is relayed directly to the motor system without first passing through a conscious decision making process, the visual feedback will not increase cognitive load (Schenk, Schindler, McIntosh, & Milner, 2005). For example, a piano roll representation is much more straightforward and economic than a frequency spectrum. Therefore it will be easier to control pitch on the basis of a piano roll like feedback. Additionally, visual feedback must also satisfy Bruner's instructional *principle of power*, stating that learners must be stimulated to make connections between topics that seem separate (Bruner, 1979). For example, while a novice might assume that pitch and loudness are separate qualities of a sound, visual feedback might make clear that playing louder might have an effect on pitch. While the principle of economy might reduce extraneous cognitive load by leaving out information that is not immediately relevant, the principle of power might reduce the intrinsic cognitive load by clarifying the relationships between the different elements and thereby reducing the perceived complexity of the information. This allows integrating these elements in a unifying schema.

Internal focus

Visual feedback can also have a degrading effect on learning by possibly inducing an internal focus of attention. Although concurrent visual feedback has been found to degrade learning, the question is not so much whether visual feedback is provided but rather on what the visual feedback focuses. Research has indicated that the degrading effect of visual feedback stems from an internal focus (on one's movements, body parts, or the feel of the movement; instrumental signals) (Wulf & Lewthwaite, 2009). Feedback that promotes an external focus is more effective than a reduced frequency of feedback (Wulf, McConnel, Gärtner, & Schwarz, 2002).

Dependency

Finally, visual feedback might induce a dependency (e.g. Ronsse, et al., 2011; R. A. Schmidt, 2008), in particular when it is concurrent. The *guidance hypothesis* (Maslovat, Brunke, Chua, & Franks, 2009; Salmoni, Schmidt, & Walter, 1984; R. A. Schmidt, Young, Swinnen, & Shapiro, 1989) postulates that increased feedback may lead to immediate benefits during performance but to decrements in performance when the feedback is removed. The efficacy of the feedback in guiding and maintaining performance possibly induces reliance because sensory processing areas have become tuned to this source of information during practice. This might prevent the learner from processing various other aspects of task-related information, such as environmental cues or response-produced feedback.

To conclude, visual feedback may contribute to knowledge construction by stimulating the coupling of action and perception in such a way that the learner acquires the necessary schemes to accurately play the musical instrument and to develop musical understanding. It is, however, necessary to use a kind of visual feedback that avoids inducing additional cognitive load, an internal focus and a dependency on the feedback. In our research, the use of visual feedback was attributed a prominent role and the above considerations have played a major role in designing the interactive music system for this research, namely the Music Paint Machine (see Chapter 5).

4.2.2. The active role of the learner

Interactive music systems are liable to give an active role to the learner. These systems respond to the learner's actions and, therefore, what happens depends on the learner. As such, learners engage in an interactive loop during which they are invited to use the feedback to regulate their own learning process. The teacher can easily take on a facilitating role, guiding the learner throughout the interaction instead of defining every step from a predefined goal to a predefined outcome.

Different models of self-regulation share a more or less similar structure consisting of three phases, namely a preparatory, a performance and an appraisal phase (Puustinen & Pulkkinen, 2001). The *preparatory* phase is related to the task (definition, motivation) and its goals (e.g. planning) as defined before an actual performance. The *performance* phase concerns monitoring (self-observation) and executive strategies (self-control). The *appraisal* phase encompasses feedback, self-evaluation and self-reflection.

Interactive systems can contribute to these three phases. They have a strong motivational power (Addessi & Pachet, 2005; A. R. Brown, 2012; Percival, et al., 2007) and can present clear tasks that, appealing to the skill level of the individual learners, contribute to self-efficacy. The feedback of these systems can stimulate self-observation, self-control (see also 4.2.1) and self-evaluation. Allowing learners to take on an active role through which they can take control over the learning process places their personal experience at the centre of teaching and learning. This means that instruction appeals to their personal interest and beliefs and builds on their previous experiences or experiences gained outside the school. Interactive music systems often integrate cutting edge technologies and this seems to appeal to the learners. Research has shown that technology is deeply embedded in the contemporary lexicon of young people's musical lives (Burnard, 2007; Folkestad, 2006).

4.2.3. Learning environment

A constructivist learning environment is knowledge-, learner-, assessment-, and community-centered. In the two previous sections, it became clear that interactive music systems can contribute to the knowledge- and learner-centeredness of the learning environment. In this section, we elaborate on the assessment-, and community-centeredness.

Assessment-centered learning environments provide opportunities to evaluate students with the objective to motivate and inform them (Bransford, 2000). We believe that interactive music systems are excellent devices to provide learners with feedback that fosters assessment for learning or formative assessment, i.e. assessment that focuses on the process of learning (e.g. eliciting feedback through peer conversations) rather than on the product of learning (e.g. examination at the end of the year). Moreover, these systems work on the basis of objective measurement and therefore they provide unambiguous feedback. Very often the learners' performances can be logged and, consequently, their progress can be made visible.

We also believe that interactive music systems can contribute to the community-centeredness of the learning environment by supporting the process of scaffolding and by stimulating learners to cross the zone of proximal development (ZPD). The zone of proximal development is defined as an area of understanding or cognitive development that is closely beyond a learner's current understanding. It is an interesting concept with regard to the implementation of interactive music systems in the learning environment in order to promote its community-centeredness. According to Vygotsky (Chaiklin, 2003; Vygotsky, Gauvain, & Cole, 1978), learning is about crossing the zone of proximal development. This allows reaching a higher level of understanding based on social interaction with a teacher or with peers who facilitate learning by providing support or scaffolding. This entails interventions that assist a learner in the process of constructing knowledge and developing understanding. Educational technologies such as interactive music systems can provide this support. Moreover, due to the highly interactive nature of current interactive music systems, these applications might be considered as scaffolders that – to some extend – take over the role of a teacher or peer. According to Pritchard and Woollard (2010) scaffolding can be achieved by adopting different approaches in which the technology takes on different roles:

- *technology as support:* provide an environment in which the learner feels at ease to suggest and try out ideas
- *technology as prompt:* nurture initiative
- *technology as provider of feedback:* reinforce positively
- *technology as simplifier:* break a problem in small steps
- *technology as motivator:* encourage learning by stimulating engagement
- *technology as highlighter:* point at elements that require more attention
- *technology as model:* demonstrate

Based on the different roles that technology can take on, interactive music systems can provide a phenomenarium (Perkins, 1992) that may elicit strong learning experiences. Moreover, the teacher might sequence these experiences in order to structure the learning process in such a way that it accommodates the current understanding of the learner but at the same time stimulates to go beyond this current understanding and cross the zone of proximal development.

As a phenomenarium, interactive music systems can structure the situation in such a way that learners become actively and autonomously involved with the content through the interaction with the system. By contributing to the creation of a learning environment in which learners are stimulated to find a problem, to imagine a solution and to develop an appropriate strategy to get to this solution, these educational technologies can help teachers to move away from purely delivering instruction. This process of discovery is much in line with Bruner's emphasis on discovery learning. It creates a situation that, when the technology is used in a social manner (i.e. involving all learners present in the classroom), may stimulate discussion and encourage peer-learning conversations. As such, educational technology may contribute to the social dimension of constructing knowledge.

To sum up, interactive music systems can contribute to establishing an optimal learning environment that is learner-, knowledge-, assessment- and community-centered. In the next section we further elaborate on the potential of interactive music systems to support instrumental music teaching and learning, based on the theory of embodied music cognition.

4.3. Interactive music systems and embodied music cognition

In the previous section it was argued that interactive music systems could possibly support a constructivist approach to instrumental music instruction. In this section we elaborate on these systems' possible contribution to an embodied approach to instrumental music teaching and learning. It is assumed that, because of their specific features, interactive systems might significantly contribute to such an approach. These features are the integration of body movement and the use of visual feedback.

4.3.1. The integration of body movement

Interactive music systems often integrate body movement as constitutive to the musical experience they provide to the learner. In this way these systems can appeal to the corporeal basis of musical engagement and meaning formation.

By implementing sensing technologies and software applications it is possible to track body movements while playing music and engaging with the system. This has two important benefits with regard to feedback and the use of the body.

One benefit concerns the assumption that the use of motion sensing technologies offers a valuable means to evaluate and monitor music playing. It enables to provide learners with the *knowledge of results* as well as the *knowledge of performance* that may complement the conventional verbal feedback, which is prone to ambiguous interpretation and characterized by a delay (Hoppe, Brandmeyer, Sadakata, Timmers, & Desain, 2006; Howard, et al., 2007). Because of the objective character of this kind of feedback, the interactive loop between playing and visual feedback might contribute to the fine-tuning of the necessary action-perception couplings. Action-perception couplings are the central mechanism of embodied cognition (Leman, 2007). They constitute the engine that allows a corporeal understanding of the music. Therefore, interactive music systems that attribute a role to gestures (intentional body movement) might contribute to an embodied understanding of music.

Another benefit of the integration of body movements concerns the sensing technology's possibility to go beyond the mere measuring and following of student's bodily behaviour by turning the body and body movements into the controller of the system. In that case, interacting with the system becomes a matter of deliberately manipulating its outcomes throughout the playing instead of merely receiving visual feedback on one's playing. Such a gestural involvement with the music might provide learners with a complementary perspective that creates the space for exploration and experimentation with body and instrument. In other words, it offers the possibility to move from the mere development of a "docile" body to the (re)discover of the body's original motility. Learners can develop ways of corporeally articulating the music while playing. Throughout these explorations the learners can acquire the necessary usage and instrument mediated action schemes and as such stimulate the process of instrumental genesis. Throughout this process learners develop a bodily motility with the instrument, which is the basis for an optimal relationship with the instrument and for a meaningful embodied engagement with the music.

4.3.2. The multimodality of interactive music systems

Next to the integration of body movement, an important feature of interactive music systems is their multimodal nature. Most often interactive music systems integrate a visual component and this way they provide an environment in which the multimodal nature of music cognition can be fully deployed in the pursuit of musical understanding. By combining the different modalities, interactive music systems can elicit an experience that intensifies the activation of the enactive and iconic mental registers or modes of representation (Bruner, Olver, & Greenfield, 1966). Moreover, by using both movements and visual representations, these systems can appeal to the different levels (see Table 4.2) of Bruner's three mental modes of representation (Antonietti, 2009).

By providing learners with an expanded multimodal experience, interactive music systems provide feedback in multiple modalities and this might intensify the musical learning processes (e.g. Ng, Larkin, Koerselman, & Ong, 2007; Yu, Lai, Tsai, & Chang, 2010). Learners are provided with a concrete experience that may serve as the experiential ground for future abstraction and reflection. As such these systems interfere with the establishment of action perception couplings (see previous section).

Table 4.2. Bruner's different forms of knowledge representation

modes	enactive *motor: doing*	iconic *visual: imagining*	symbolic *verbal: describing*
levels	neuro-vegetative *(e.g. heart rate)* gestural *(e.g. feet tapping)* complex patterns *(e.g. dance)*	synaesthetic *(e.g. sound as "dark")* topological *(e.g. continuous vs. broken)* Visuospatial *(e.g. approaching)*	onomatopoeic *(sound imitates something)* prosodic *(as if speaking)*

To sum up, the considerations mentioned above suggest that interactive music systems provide access to music and musical meaning in a way that might complement the teacher-directed approach of verbal description and aural modelling. The use of body movement stimulates the development of a corporeal understanding through a corporeal attunement to the music and through the process of corporeal imitation. Finally, the integration of sound, movement and visuals appeals to different sensory modalities and thereby acknowledges the multimodal nature of the involvement with music.

CHAPTER 5

The Music Paint Machine

In this research project, an interactive music system, called the Music Paint Machine, has been developed and tested. This system allows a musician to make a digital painting by playing a musical instrument and by moving his/her body on a coloured pressure mat. The sound and movement of the musician are tracked (A), analysed (B) and transformed (C) into a visual output (D). Musical parameters (e.g. pitch, loudness, duration) and movement parameters (e.g. bending or turning the torso, moving the feet on the coloured mat) are transformed into visual parameters (e.g. vertical position, horizontal position, thickness of a line or dot, colour). In figure 5.1 we present an overview of the system.

The concept of the Music Paint Machine originated from the practice-based insights with regard to the didactic potential of visual feedback and movement exercises, following the researcher's teaching experience in formal instrumental music education (see Chapter 8). Based on these early intuitions it was possible to suggest the essential elements and features of the system. These were further elaborated on the basis of the theoretical investigation of the musician-instrument relationship (see Chapter 7) and on the basis of a combination of the embodied music cognition paradigm with a constructivist approach to teaching and learning (see Chapter 3). An important part of this elaboration was related to the concept of optimal experience as captured in the notions of flow experience and the feeling of presence (see section 5.1.3 and Chapter 7 and 8).

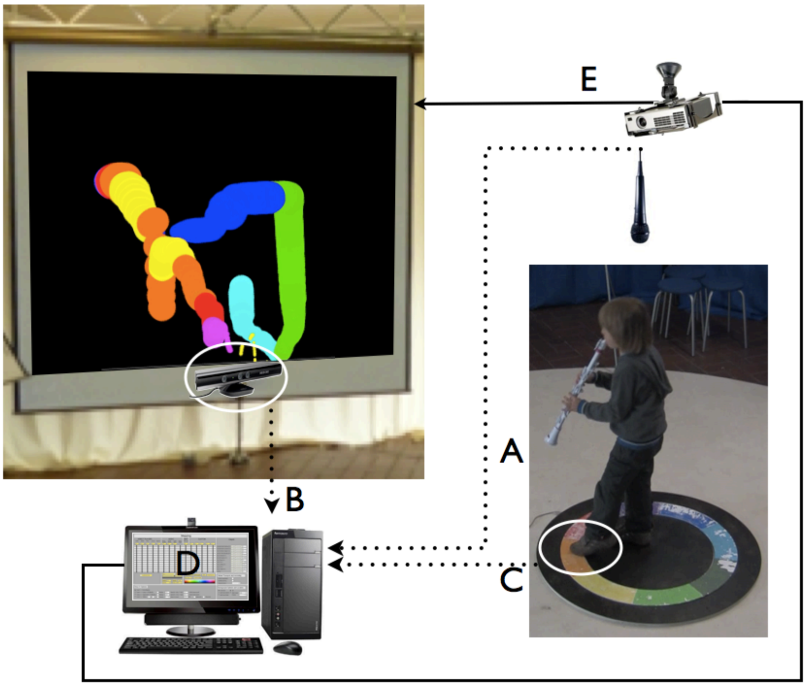


Figure 5.1. The different components of the Music Paint Machine. Sound (A) and movements (B, C) of the player are tracked, analyzed en computed (C) and projected on a screen (D).

The practical experience and the theoretical elaborations have led to the core elements and features of the Music Paint Machine, namely visual feedback, body movement, a broad spectrum of ways to use the system and optimal experience. The next sections elaborate on the core elements and features of the Music Paint Machine's (5.1) and on the hard- and software (5.2).

5.1. Core elements and features of the Music Paint Machine

At the heart of this research project is the conceptual design of the application that would allow investigating the research question, that is: *How can an interactive music system contribute to the development of an embodied understanding of music when learning how to play a musical instrument?* The goal was to design an interactive music system with a solid theoretical ground, inspired by the daily practice of teaching. This resulted in a number of essential elements and features (see Figure 5.2).

In the next paragraphs, we elaborate on these distinctive features of the system, in its current state, with regard to the visual feedback (5.1.1), the use of body and body movement (5.1.2), optimal experience (5.1.3) and a broad spectrum of practices the system (5.1.4).

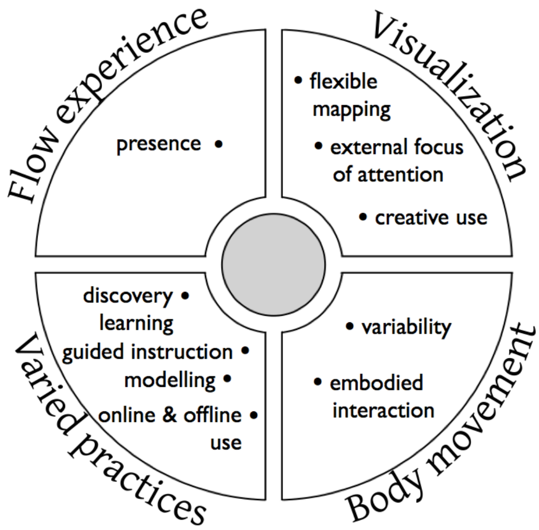


Figure 5.2. The four essential features of the Music Paint Machine

5.1.1. Visualization

Flexible mapping

Many currently developed interactive music systems for music learning integrate the use of visual feedback in order to optimize the learning process. Both movement and sound are mapped to a diversity of visual representations, ranging from augmented scores to a visual representation that exactly copies the gestures of the musician. Most of the currently used applications are based on visualizing objective data in an iconic way (see section 4.1.). That is, data retrieved from measuring the performance (e.g. pitch, loudness, duration, movement) are displayed by ways of pictorial representations that provide knowledge of results, knowledge of performance or the combination of both. The Music Paint Machine also relies on the measurement of the performance but differs, we believe, from other systems in the way it provides visual feedback and in the way it envisions the use of the feedback (see also 7.2.3).

The Music Paint Machine is conceived of as an "artistic" measurement tool. It provides both teachers and learners with a digital "painting", a kind of visual representation of the performance that appeals to imagination more than the usual iconic or symbolic representations of objective measurement data. It is believed that this kind of visual feedback might enable an "enactive interaction", i.e. a direct, natural and intuitive interaction based on motor skills (Leman & Camurri, 2006; Zanolla, et al., 2011). By augmenting the musical experience with a visualization of music and movement, the transmission of enactive knowledge might be stimulated. Therefore, the system's visual representation is based on a straightforward mapping that allows the immediate grasping of the effect of one's action, thereby allowing the direct – effortless – perception of the visual representation and, accordingly, reducing additional cognitive load. In particular, extraneous and intrinsic cognitive load are avoided on the basis of two features, namely a dynamic mapping and an adaptable range of the mapped values. Both features allow coping with the economy and power of instruction (Bruner, 1966) by constituting the flexibility of the system to shape the interaction in function of the learning content.

- *Dynamic mapping*:

  The system's mapping can be chosen in function of the learning context. This entails that not only the mappings can be switched (e.g. "loudness to size" into "loudness to saturation") but they can also be reduced in number (e.g. no mapping of loudness, no use of colours). Adapting the mapping is easily done with the system's interface, on the basis of a grid that allows connecting movement or auditory features to features of the visual output (see Figure 5.3).
  The dynamic mapping is an essential feature that allows the mapping to be straightforward in function of the learning content. This way, it is possible to reduce both intrinsic and extraneous cognitive load. For example, when learning how to play softer or louder (dynamics), pitch might not be mapped at all and the range of stroke thickness might be amplified. But when learning how to play softer or louder, pitch might be mapped again but with a reduced range of notes in order to better notice the effect of loudness on pitch. Therefore, choosing an appropriate mapping might help to structure the learning content and allow the use of incremental steps towards the learning goal.

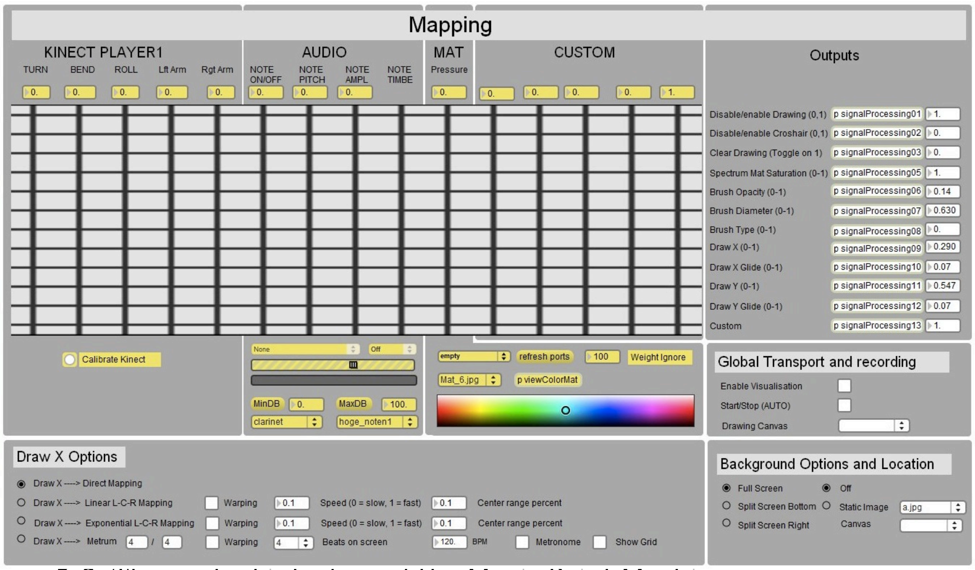


Figure 5.3. The control interface of the Music Paint Machine.

- *Dynamic range of mapped values*

Another way to influence the mappings is the possibility to adapt the ranges of the mapped features. The system calculates all incoming data on a scale from 0 to 1 (see Figure 5.4). The minimum and maximum values can be set in advance. For example, when loudness is scaled to stroke size, it is possible to input the softest and loudest note a learner can play and to use these values as minimum and maximum.

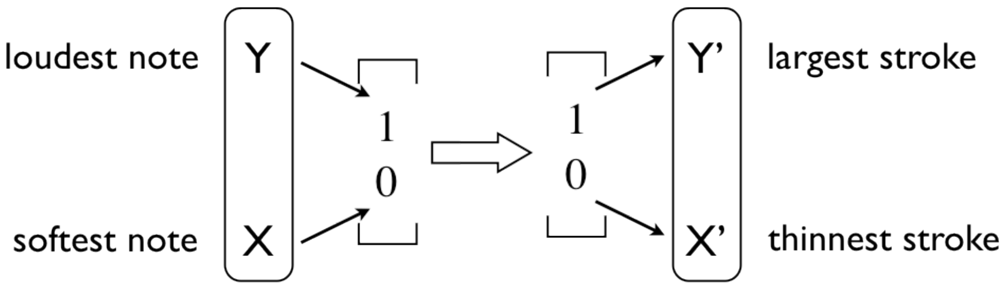


Figure 5.4. Ranges of in- and output can be controlled to fine-tune the system to a player's skills

Again this feature can be used to reduce both intrinsic and extraneous cognitive load in order to create a learning context that optimizes the learning process. But it is also an ideal way to adapt the system to the learner’s capacities. Accordingly, it is possible to connect to the learner’s current skill level and at the same time to stimulate to go one step further.

The dynamic and adaptable nature of the mapping of sound and movement to a visual representation helps to establish a (digital) learning environment that can be tailored to the four themes of constructivist instruction as advocated by Bruner (1960, 1966, 1979). These themes are the readiness of the learner, the structure of the learning content, the sequence in which the content is presented and the motivation of the learner.

The first theme is the *readiness of the learner*. Instruction must be concerned with the experiences and contexts that make the learner willing and able to learn. Therefore the learner must be motivated. Providing experiences with an interactive music system such as the Music Paint Machine may contribute to motivating the learner by eliciting an optimal experience. These kind of experiences have been proven to promote learner engagement (Shernoff & Csikszentmihalyi, 2009). But motivation alone is not sufficient. The learner must also be able to learn the presented learning content. Presenting the content in a (re)cognizable manner is therefore of vital importance. It is assumed that the Music Paint Machine's features allow to present musical content in a manner that is (re)cognizable to all learners. Different aspects of the music, such as pitch and melodic contour, length and intensity of notes are made visible to the learner in a very straightforward way.

The second theme is the *structure of the learning content*. Learners must understand the structure of the content, and not simply memorize facts about it. This will allow them to incorporate new information into this structure and to see relationships between and among different bodies of knowledge. Therefore, presenting the learning content in a (re)cognizable manner involves structuring the content in a simple form that can be most readily grasped by the individual learner. The Music Paint Machine allows simplifying the learning content and presenting new content in small steps, adapted to the learners' current skill level.

The third theme is the *sequence in which content is presented*. Sequencing learning content depends on different aspects, not in the least the individual learner's progress. However, according to Bruner, an optimum sequence most likely moves from economical to complex and from concrete to abstract. Therefore new learning material should be repeatedly presented following a progression from enactive to iconic to symbolic representation of the learning content. These representations correspond to three systems of organizing knowledge (Bruner, 1966, 1968). Enactive knowledge is constructed on the basis of motor skills, such as playing a musical instrument. That is, objects are understood by the actions that have been performed with it. Iconic knowledge is based on visual structures and recognition. This kind of knowledge is no longer action-based but still stimulus-dependent. Symbolic knowledge is abstract knowledge proper for cognitive functions such as language and mathematics.

The Music Paint Machine aims at providing the learner with an experiential ground that stimulates the construction of enactive knowledge by augmenting the sensorial experience and by promoting sensory integration of visual (screen), auditory (music), and kinaesthetic (playing the instrument and moving the body to control the system) stimuli. While the interaction with the system provides this experiential ground, the offline use (see also 5.2.4) of the visual feedback in combination with other learning materials might enable a learner to move from the enactive knowledge constructed in the interaction to iconic and to symbolic knowledge. A fine example of this is how note values can be learned by moving from the experience of painting long or short lines (playing long or short notes) to an iconic representation of note duration (short and long lines) to note values (eight and quarter notes) as the symbolic representation of note duration (see Figure 5.5).

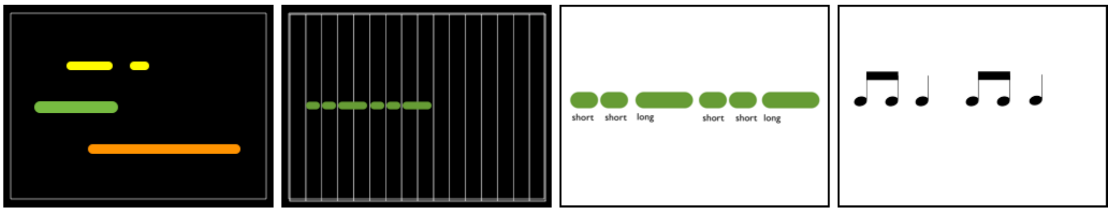


Figure 5.5. Painting pitch: an enactive basis for symbolic representation.

A fourth theme is the *motivation of the learner*. Motives for learning must preferably depend on the arousal of interest in the learning content. It is assumed that the Music Paint Machine might arouse interest by providing learners with an experience that is different from the ordinary. The use of technology, the feeling of autonomy while making one's own painting, the interaction between learners while making a painting, or the use of colours to present musical content are examples of aspects that might stimulate a positive interest in the learning content.

External focus

Another aspect of the Music Paint Machine's visualization is the focus of attention that it aims to induce by providing the visual feedback (see also 7.1.2).

The visual feedback of the Music Paint Machine is based on an objective measurement of the learner's movements and sound. The combination of both measurements results in a digital painting. It is assumed that this will lead to an external focus. First, interacting with the system is not primarily perceived as a monitoring activity but as the activity of making a painting. Consequently the focus is likely to be on the screen. Second, the visual representation is largely based on the effects of one's playing (see Table 5.1). Even if movements are measured, the system draws attention to the result (external) of these movements and not to the nature (internal) of the movement.

Table 5.1. Internal vs. external focus when playing a violin.

	INTERNAL FOCUS (how)	EXTERNAL FOCUS (what)
pitch	finger position on string	frequency
timbre	bow pressure	spectrum
loudness	speed and pressure of the bow	amplitude

Next to the straightforward mapping in function of the learning content, the visualization of sound and movement can be interpreted as a "musical map" (Blair, 2008). Because of the straightforward mapping, this musical map can be said to represent a musical gesture.

Creative use

In contrast to many existing interactive music systems that use visual feedback, the primary aim of the system is to engage learners in an interactive loop in which the learner develops playfulness with sound, movement and visualization. In particular, the combination of sound and movement might invite learners to transcend their habitual way of playing and to be creative with all aspects of playing music. Being able to control the visual aspects on the basis of bodily and musical gestures can stimulate to experiment with his/her body and with musical parameters. It encourages improvising. By providing a familiar "thing" to do, namely make a painting or drawing, it offers learners the opportunity to "let go" and to play something from scratch. The creative use of the visual feedback might therefore facilitate improvising because the focus is no longer on the improvisation, thereby freeing the mind from worries and self-doubt. Everybody can paint or draw something. It even can become a challenge to paint complex, beautiful or funny pictures by playing the musical instrument. This way, learners might gain confidence and audacity to improvise. It is assumed that this particular use of the visual feedback introduces a playful musical experience that fosters the learners' motivation and engagement. Therefore, stimulating an optimal experience is essential in order to the use of the Music Paint Machine.

An additional benefit of the creative use of the Music Paint Machine concerns the possible dependency on the visual feedback. We believe that the specific use of the visual representation enables providing feedback without making the performance dependent on the feedback. Rather we see the interactive loop between player and painting as constitutive to the experience of engaging with the system. The player controls the system but is invited by the possibilities of the system to go beyond the mere control and to be creative with sound and movement. In figure 5.6. we present some of the paintings.

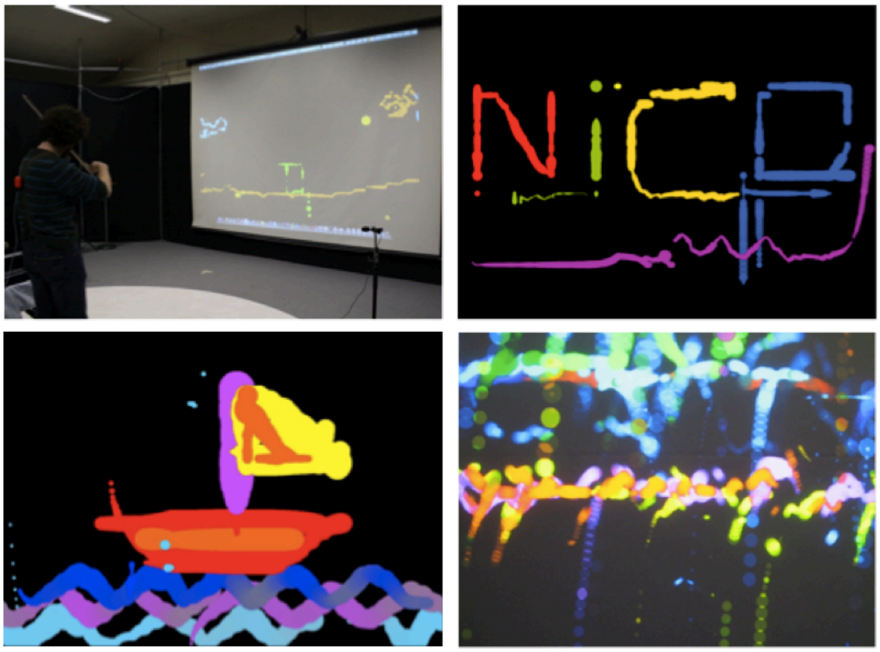


Figure 5.6. Different creative outputs that resulted from engaging with the Music Paint Machine.

To sum op, the characteristics of the visual representations of the Music Paint Machine are likely to avoid additional extraneous and intrinsic cognitive load because of its adaptability to the learning content (dynamic mapping & range). Furthermore, the system is likely to induce an external focus thereby avoiding a degrading effect on learning. The creative use of the system elicits a playful character that might motivate students to engage with the system. It also might stimulate them to explore, experiment and improvise. It is assumed that the creative use of the system avoids learners to become dependent on the visual feedback.

5.1.2. Body movement

Like a growing number of interactive music systems, the Music Paint Machine monitors the movements while playing the instrument. However, the Music Paint Machine does not merely monitor movements in function of developing playing techniques. When engaging with the Music Paint Machine, the learner's movements can play an active role in actually controlling the system. The integration of specific body movements and instrument playing as controller of the system has two purposes: developing bodily awareness and understanding through variability of movement, and promoting an optimal relationship with the musical instrument through an embodied interaction with the system.

Variability: Developing bodily awareness and understanding through bodily motility

By using movements to control the system and make a painting, the Music Paint Machine provides an environment in which movements can be used in different ways. It is believed that the deployment of this variability will stimulate the development of body awareness and possibly increase bodily – or enactive - knowledge, i.e. improved knowing in and through the body (Juntunen & Westerlund, 2001). This way of approaching the body is related to the idea of *differential learning* (Schöllhorn, 2000) and to *the variability of practice hypothesis* (R. A. Schmidt, 1975).

In the *differential learning approach,* a priori defined idealized performance patterns ("templates") are replaced by subject- and context-dependent performance patterns, helping learners to find their individual optimal performance pattern for given complex motor skills (Frank, Michelbrink, Beckmann, & Schöllhorn, 2008). Therefore, movement patterns are intentionally varied during practice. These variations induce a certain noise into the activity of playing the instrument. According to the dynamic system theory, the learner can detect an "ideal" movement through the addition of noise (Savelsbergh, Kamper, Rabius, De Koning, & Schöllhorn, 2010). Moreover, adding noise to a certain target movement might provide a broader array of potential solutions. In a way, one could say through the noise the familiar is made strange, and in so doing, it becomes possible to experience the degrees of freedom in one's movements (Sheets-Johnstone, 2010). According to Gordon (1997) the freedom to explore movement develops a relaxed feeling when moving, which is the best foundation for music instruction.

The Music Paint Machine introduces "noise" by inviting learners through its mapping to use a combination of task-related and non-task related movements. Task-related movements can be viewed as movements that are related to different kinds of gestures as categorized by Jensenius et al (Jensenius, et al., 2010), especially sound-facilitating gestures for phrasing (see Figure 3.2) or sound-accompanying gestures that follow aspects of the music such as strong and weak beats (see Figure 3.3). Non-task related movements stem from the system's use of body movement to control certain visual parameters. For example, bending the torso may change colour transparency or colour saturation; the feet can be used to merely choose a colour rather than to follow some aspect (e.g. the beat) of the music.

Schmidt's *variability of practice theory* postulates that variability in practice conditions is important for learning motor skills, such as those required for playing a musical instrument (R. A. Schmidt, 1975). The variability refers to the variety of movements and situations the learner experiences while practicing a skill. According to Sweller (1994), the primary mechanisms are schema acquisition and automation. The variability of practice facilitates these mechanisms by strengthening the recall schema (produce a movement) and the recognition schema (evaluate the correctness of the response).

The Music Paint Machine aims at contributing to this process by allowing a learner to move from "I must" (docile body) to "I can" (motile body). It provides a learning context in which the variation of movement and conditions can be introduced. The possibility to control what happens on the screen invites learners to explore and experiment with body movements out of curiosity for the effect these movements might generate. Painting in different colours, making different shapes, or using different drawing directions are such ways in which a musical motive can be played. When trying to play in different ways it becomes possible to find the invariant through variations, namely the felt quality of movement (Sheets-Johnstone, 2011). The learner becomes more sensitive to and aware of kinaesthetic sensations. This way, the system might evoke an experience in which the body becomes an intimate context for knowing. It is assumed that, through the bodily sensing, feeling and experiencing of the musical sounds in combination with the visual representation, the Music Paint Machine supports developing the ability to feel the music from within and, accordingly, an embodied understanding of the music (Bowman, 2000, 2004; Shepherd, 2002). Moreover, using this experiential ground and the kinaesthetic awareness it induces, as a learning content is another fruitful step towards understanding.

With regard to the variability of movement that the system introduces, two critical remarks must be made.

First, it might be argued that the introduction of non-tasks related movements interferes with, especially, sound production gestures but maybe even with sound-facilitating or communicative gestures. However, the Music Paint Machine's does not seek to replace the "normal" way of playing but is meant to play a complementary role to other didactic practices. It might also be argued that making the supposedly wrong or unnatural movements might augment awareness of the right or natural movements. Finally, the process of integrating the non-task related movements within one's playing might support restoring the body's original motility by expanding the learners freedom to move while playing.

Second, the extensive use of movements might include motor load and, consequently a degraded learning effect because of an internal focus. The use of movement in the Music Paint Machine tries to cope with this pitfall by mapping movements to the digital painting and by a specific way of addressing body movements. It is assumed that the visual feedback or "painting" is more likely to induce an external focus because the movements of the player generate a visual effect (e.g. go to left or right, or change the colour saturation). Furthermore, the Music Paint Machine invites learners to engage in a creative use of the body by encouraging variations of movements. As such, it aims at the development of a "motile" unity of body and instrument rather than a "docile" body that is tamed into templates of right posture and movements in order to master the instrument. Accordingly, the function of the digital painting as feedback is very different from that of the usual visual feedback resulting from body movements.

Embodied interaction: Promoting an optimal relationship with the musical instrument

The establishment of an optimal relationship with the musical instrument can be considered to be at the core of instrumental music instruction. In our view, such a relationship is characterized by the experience of unity, in which the musician experiences the musical instrument as a natural extension of the body (see Chapter 7).

The Music Paint Machine aims at supporting the development of such an optimal relationship by providing an experience in which the learner can engage in an embodied interaction with the music. During such an interaction the musician experiences the so-called illusion of non-mediation, i.e. the musical instrument becomes transparent in use to such a degree that the musician no longer experiences a border between body and instrument (see Chapter 7). Therefore an embodied interaction with the music is a condition in which the unity of musician and instrument is established. It is assumed that the frequent occurrence of an embodied interaction contributes to the process of instrumental genesis (see section 3.2.2.) and as such to the development of the utilization schemes that underlie the experience of unity.

On the basis of its specific features, the Music paint Machine aims at evoking an embodied interaction by contributing to the basic components of an embodied interaction (see Figure 5.7). These are a direct perception of the musical environment, a skill-based playing and, based on these two components, an optimal experience or “flow experience” (Csikszentmihalyi, 2008), which is an immersive experience that brings enjoyment and intrinsic motivation (see Chapter 7 and 9).

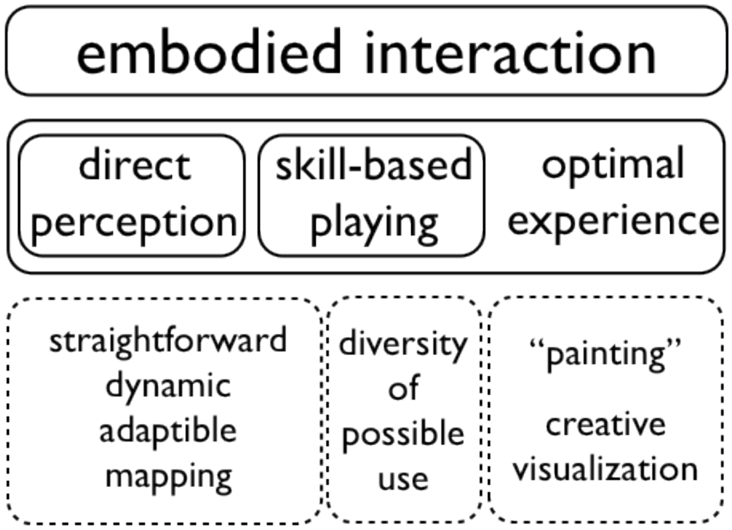


Figure 5.7. The MPM's features are tailored to the principal components of an embodied interaction.

To enable a direct perception of the visual representation of sound and movement, the system uses a straightforward mapping that is dynamic and highly adaptable to the learning context. Skill-based playing is enabled because of this dynamic adaptability and because it offers a broad spectrum of possible uses (see 4.1.3). Flow experience should be stimulated by the game-like character of the system (playing with music, movement and visuals) and by the creative visualization.

Flow experience is intrinsically related to direct perception and skill-based playing on the basis of several of its dimensions, namely a balance between the perceived challenges and one’s skills, immediate feedback, the sense of control and the merging of action and awareness (Csikszentmihalyi, 2008). Therefore it is assumed that eliciting a flow experience may foster the optimal relationship with the music instrument. Every time a learner or musician experiences flow, the music instrument becomes transparent in use, i.e. it disappears from consciousness while playing. A repeated flow experience might render the mental schemes that accompany the feeling of unity with the musical instrument more permanent, resulting in the acquisition of a long-term intuition, even when the instrument is not at hand.

The Music Paint Machine might contribute to such a repeated occurrence of flow experience while playing the musical instrument. The design of the system aimed at facilitating the flow conditions, in particular the balance between skills and challenges, the immediate and unambiguous feedback, and clear goals.

First, the adaptability of the mapping and of the ranges of the measured values allows the teacher to create a learning context that appeals to the current skill level of the learner. An example is the ability to adapt the screen height to the range of notes a learner can play (see Figure 5.8).

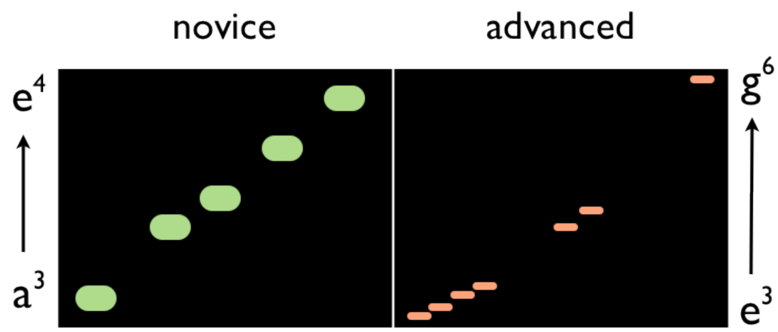


Figure 5.8. The screen height of the Music Paint Machine's visual output can be adapted to the player's tessitura (range of notes).

Second, what appears on the screen is based on the objective measurement of the learner's playing (sound and movement). Therefore, the visualization of movement and sound provides immediate and unambiguous feedback on one's playing. For example, if a learner wants to play crescendo (louder and louder) on the clarinet but intonation changes because of low lip pressure, this will be reflected on the screen by a slightly curved line (see Figure 5.9).

Third, the system allows activities that are characterized by clear goals. For example playing a long note by drawing a line from one side of the screen to another, using a predetermined combination of colours or drawing a specific shape.

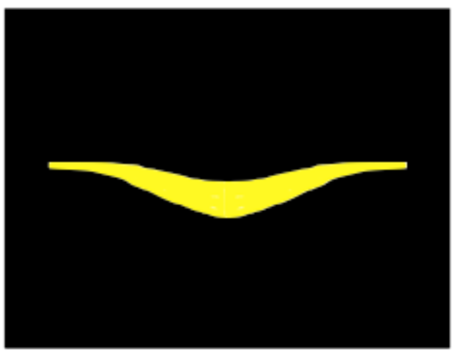


Figure 5.9. The system shows when intonation changes when, as exemplified in this figure, the musician plays crescendo and diminuendo.

To sum up, the Music Paint Machine is designed to facilitate the direct perception of the musical environment, a skill-based playing and, based on these two components, an optimal experience or "flow experience". It is assumed that the specific kind of visual feedback and the specific use of body movement play a distinctive role to engage the learner in an embodied interaction through which the relationship with the instrument can be optimized.

In the next section, we further elaborate on the importance of an optimal experience while engaging with the system and in particular on the bodily basis of such an experience.

5.1.3. Optimal experiences

The notion of optimal experience, as captured in the concept of flow experience, has played a major role in designing and empirically testing the Music Paint Machine. It is a central concept in the investigation of the musician-instrument relationship (see section 5.2.2. and chapter 7) and it is linked to the constructivist learning environment (see section 3.1.3).

Due to the important role of body movement for the Music Paint Machine, it was necessary to elaborate on the bodily basis of optimal (flow) experience and on the role of the artefacts (musical instrument, the Music Paint Machine). This was done by refining the concept of flow experience on the basis of the concept of presence (see Chapters 8 and 9).

Presence is a layered process that relies on a coherent collaboration of bodily sensations, perception and cognition to keep one's attention focused on the activity (Riva, Waterworth, & Waterworth, 2004). The first layer, *extended presence*, is cognitive. It occurs when the content of consciousness is experienced as meaningful on the basis of one's intentions, beliefs and personal preferences. The second layer, *core presence*, is perceptual. It entails the selective attention to environmental stimuli and is intrinsically coupled to the core affects, i.e. the core of emotions and moods that influence perception, cognition and behaviour (Russell, 2003). The third and most profound level is *proto presence*. This level concerns bodily sensation. Here the sensorimotor coupling of action and perception plays a defining role. Actions are anticipated and unconsciously monitored on the basis of sensorimotor expectations. The bodily sensation of a positive match between action and perception leads to proto presence. Accordingly, this level is responsible for the sense of control that is characteristic for flow experience.

The Music Paint Machine aims at providing the learner with an experience in which the interaction with the painting captivates the learner's attention on the level of sensation, perception and cognition. By transforming movement and sound into a visual output, the system creates an augmented musical environment and thereby affects the learner's involvement in this environment at the level of proto-presence (bodily sensation), at the level of core-presence (perception), and at the level of extended-presence (cognition). Therefore, the Music Paint Machine is assumed to affect the musician's sense of presence while painting with movement and sound.

First, it is assumed that engaging with the system affects proto presence by deploying specific body movements such as moving the feet or bending and turning the torso. When playing with the Music Paint Machine the body is used in ways that can be unusual with regard to the sound-accompanying, the sound-facilitating and the communicative gestures of "normal" playing. It is assumed that the use of these additional movements might stimulate a bodily engagement with the task and thereby intensify the bodily sensations.

Second, it is assumed that the Music Paint Machine affects core presence through the feedback it provides. Due to the mapping of sound and movement to the visual domain, one could say that what appears on the screen is a visualization of sensory trajectories (see Figure 5.10).

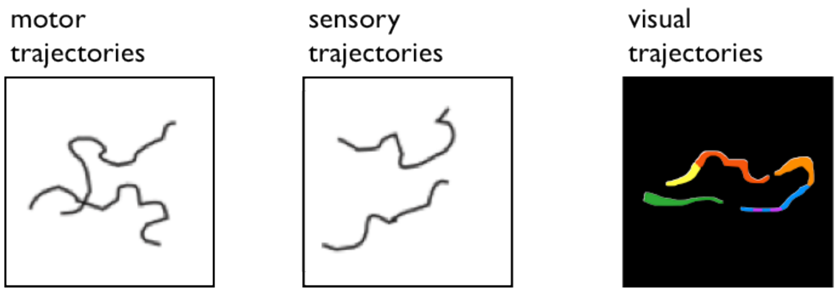


Figure 5.10. Motor and sensory trajectories merge into a visual trajectory due to the mapping of movement and sound to visual features

This visual representation of sensory trajectories might contribute to presence as monitoring mechanism and allow the non-mediated (pre-reflexive) perception of successfully transforming intentions (paint this or that) in action (play music and move) within an external world (sound and visualization) (Riva, 2009).

The painting functions as visual feedback and informs the learner whether certain intentions are successfully enacted. Using the Music Paint Machine may therefore affect the creation of action-perception couplings that are crucial for determining the extent to which intentions are successfully enacted, so that the sense of presence can occur (Zahorik & Jenison, 1998). Accordingly it enables correcting one's actions in order to make all sensory information consistent. This process of rendering the auditory, kinaesthetic and visual feedback consistent can become an unconscious monitoring process. This way,, the Music Paint Machine may contribute to the establishment of the necessary fine-tuned action-perception couplings that constitute the interaction with the music and that underlie the fine-grained control over the instrument.

A characteristic of the feeling of presence, is the experience of “being there”. When action and awareness merge, a person is acting proximally (“here”) but thinking distally (“there”) (Loomis, 1992; Polanyi, 1967). That is, consciousness is being occupied with the sensory trajectories (feedback on the result of playing the instrument, non-instrumental signals, outer world) rather than with the motor trajectories (feedback on the technical handling of the musical instrument, instrumental signal, inner world). Maximal presence or the “feeling of presence” occurs when all levels of presence are activated. This happens when all levels of consciousness (sensation, perception, cognition) are occupied with the results of one’s actions. When this happens and the non-instrumental information fully captures the attention, instrumental signals vanish from consciousness and the musical instrument is unconsciously considered as an aspect of the self. This results in the intuitive apprehension of the fusion between musician and musical instrument or the so-called illusion of non-mediation.

Whether an optimal experience occurs is highly dependent on the nature of the activity in which the learner engages. To allow a teacher to optimally shape this activity and thereby to create a powerful learning environment in which the learner might experience flow, the Music Paint Machine is designed to be highly adaptable. As such, the Music Paint Machine enables a broad spectrum of didactic practices. In the next section, we will elaborate on these practices.

5.1.4. A broad spectrum of practices.

In the previous sections it was shown that the Music Paint Machine is a highly flexible, versatile and adaptable system. The main idea behind this protean nature (Mishra & Koehler, 2003; Papert, 1980) is the shaping of the interaction with the system in function of the learning content. Next to the dynamic mapping of movement and sound to a visual representation and the adaptable range of the mapped values, the system can be used in many different ways. The broad spectrum of possible uses can be subdivided into two principal modes: the *explorative mode* based on (enhanced) discovery learning and the *learning path mode* based on guided instruction and modelling. Furthermore, the system can be used online and offline. The former focuses on engaging in a closed loop with the digital painting under construction (process). The latter focuses on the digital painting as pedagogical documentation (product) for further reflection.

(Enhanced) discovery learning, guided instruction and modelling

The Music Paint Machine has been designed to allow different approaches to teaching and learning that can play a complementary role to shape the musical learning process.

First, it allows the creation of an environment that fosters exploration and experimentation. In this mode, the screen becomes a canvas for free expression, inviting the learner to tryout different ways of playing with movement and sound and in particular with the combination of both. The system provides an experience in which the learner can make “mistakes” and even use “wrong” ways of playing to create a painting. This mode is linked to discovery learning, possibly enhanced by the teacher’s strategies (see also section 3.1.2.). For example, the exploration with movement and sound can be organized at times with a minimal instructional guidance and thus endowing learners with a maximal sense of autonomy. At other times, the teacher might guide the exploration by providing feedback, asking questions or suggesting some approaches. Furthermore, the exploration and experimentation can be structured by adapting the system’s mapping and mapped values. That way way the range of possible actions can be reduced or broadened in function of embedding the discovery learning within a learning path.

Second, the system allows designing exercises in function of a methodically constructed learning path. By giving learners specific tasks, knowledge and skills can be gradually built up towards a specific learning goal. For example, learners can be asked to play a scale with a certain note value (e.g. whole note) or rhythmic pattern (e.g. 4 quarter notes) for each note of the scale and additionally to move the feet in a specific way by imposing a certain sequence of colours (see Figure 5.11). This way, learners learn about strong and weak beats.

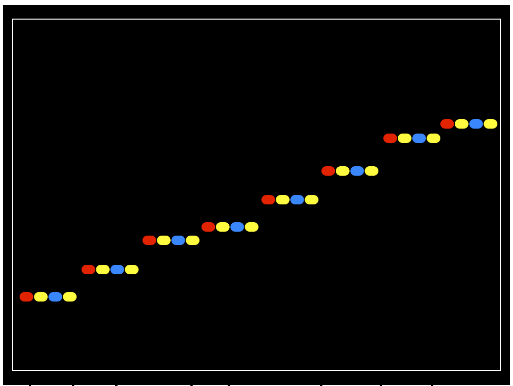
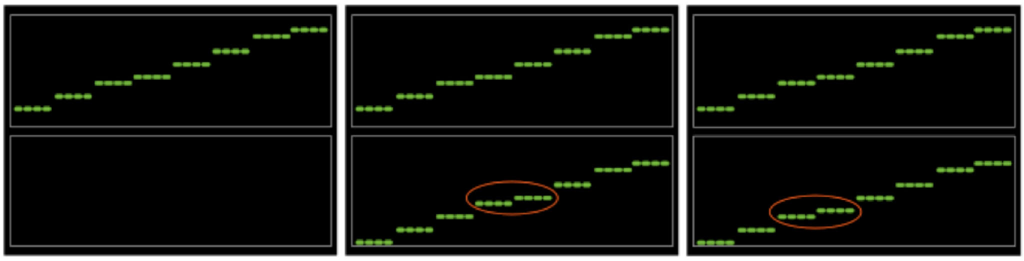


Figure 5.11. Visual output when playing each note of a scale four times. A fixed pattern of colours is used to indicate strong and weak beats.

Third, the system can be used to provide visual models to the learner. It is assumed that the learner will acquire certain skills or knowledge by imitating the model. These models can be different melodic contours that range from being very simple (e.g. ascending or descending) to being more complex (combination of ascending and descending). They can also be rhythmic patterns (e.g. rhythmic patterns of the next song to be learned), dynamic patterns (e.g. crescendo or diminuendo) or specific movements (e.g. colour per beat or colour per measure). An important aspect and benefit from a pedagogic viewpoint is the "openness" of the visual model. One visual model can be used for different notes.

For example, a visual output can become a model for the learner that might support learning different major scales. Suppose students have learned to play G major, they can be asked to play it in the top screen (see Figure 5.12a). Next they may be asked to duplicate the visual model in the bottom screen by starting with an "f". If they have not learned F major yet, they might not play a b flat. This would result in incorrect duplication of the previous painting, which was displayed in the top screen (see Figure 5.12b). The mismatch of both paintings is a problem and thus results in a learning opportunity by reflecting on the problem and by trying to find a solution. If they already have learned to play the b flat, they might easily correct it (see Figure 5.12c). If not, this is an excellent opportunity to learn a new note, the b flat.



a b c

Figure 5.12. Playing scales with the Music Paint Machine. The split screen allows comparing two paintings. Mismatches are opportunities for learning. Here the mismatch concerns the semitone in a major scale (see text for explanation).

Online and offline use

The Music Paint Machine can be used to provide learners with an experience in which they engage in an interactive loop with the painting, which functions as a kind of visual feedback. The playing is shaped by what happens on the screen and is, possibly, instantaneously adapted. Here the possibilities of the system and what appears on the screen function as invitations to act (if not having a pre-defined goal) or to enact (if having a predefined goal). In this "online" use, the process of interacting with the system is at the core of the learning process. In the "offline" use, occurring after the interaction, the product that results from the interaction is at the core of the learning process. As a kind of pedagogical documentation (Vecchi, 2010), i.e. a visible trace that captures what the learner did during the interaction with the system, the painting becomes a starting point for reflection and for thinking aloud (assess and explain) about what they did and why. The painting can stimulate a dialogue between learners and teachers in which understanding is built on a collaborative basis.

To conclude, the concept of the Music Paint Machine has a firm theoretical foundation that, inspired by the daily practice of teaching, provides a sound basis for the development of the appropriate hard- and software. Aiming at an immersive experience that, through an embodied interaction, stimulates bodily awareness and understanding, and promotes an optimal relationship with the instrument, the system might support instrumental music instruction in a meaningful way. The protean nature of the system allows for a spectrum of practices that can support both the realization of specific learning goals as steps in a methodologically organized learning path and creative explorations and experimentations.

5.3. Hard- and software of the Music Paint Machine

In this section, we outline some components of the hard and software. In particular, we sketch the evolution of the system.

5.3.1. Motion sensors

The first prototype of the system tracked movements on the basis of two inertial MTx sensors from Xsens (see Figure 5.13a). One sensor was attached to the musician (A); another sensor was placed on a fixed point (B). Body movements were tracked by using the relative difference in orientation between both sensors.

The second prototype tracked movements with a Sparkfun Razor 9DOF inertial sensor (http://www.sparkfun.com/products/9623) (see Figure 5.13b). This wireless motion tracker incorporates four sensors: a single-axis gyrometer, dual-axis gyrometer, a triple-axis accelerometer and a triple-axis magnetometer, resulting in nine degrees of inertial measurement.

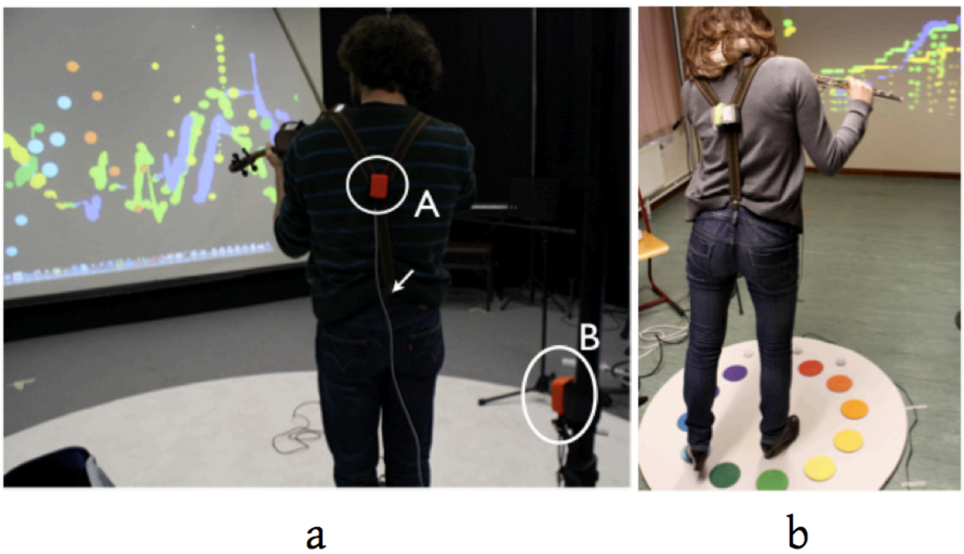


Figure 5.13. The first proto type used the relative orientation of two sensors (A & B) that were connected to each other (a). The second prototype used a wireless inertial sensor.

In the third prototype, movements were tracked with a Kinect® sensor. This commercially available device detects the user body position without any wearable devices or markers on the body. This enables unobtrusive body tracking but also allows the integration of functional movements, i.e. specific movements that are used to control the system. For example, raising the right arm above the head clears the screen and raising the left hand above the head brings the cursor to the left side of the screen. Furthermore the Kinect® sensor allows to delineate an area. For example, the system starts to work as soon as someone enters a part of the traceable space. In the case of the Music Paint Machine, the system says “hello”, starts tracking the music and the body movements and starts logging as soon as somebody steps on the coloured sensor mat. It says “goodbye” and stops tracking and logging when leaving the mat again. An additional benefit of defining such an area is that it avoids tracking the movements of the other learners and teacher in the classroom. This way, they cannot interfere with the interactive loop of the learner who engages with the system.

5.3.2. Coloured mat

The colour mat used in the first and second prototype (see Figure 5.14a) was not pressure sensitive. In the first prototype, switches were constructed from 2 CDs covered with aluminium foil. On the back of these CDs, the wires were held together with the aluminium foil and electric conducting glue (see Figure 5.14b,c). The back was covered and protected by a securely fixed CD. A 4cm isolating adhesive tape, placed in the middle of these sets of double CDs, keeps the sets at a distance of about 3mm. The USB interface was a hacked numeric keypad. The twelve contact switches replaced the button switches of the original keyboard matrix.

a b c

Figure 5.14. The coloured pressure mat and its parts.

The second prototype had monostable micro switches (see Figure 5.15) which caused the switches to be more robust. An arduino board was used to send a number, relative to the colour switch, to the computer.

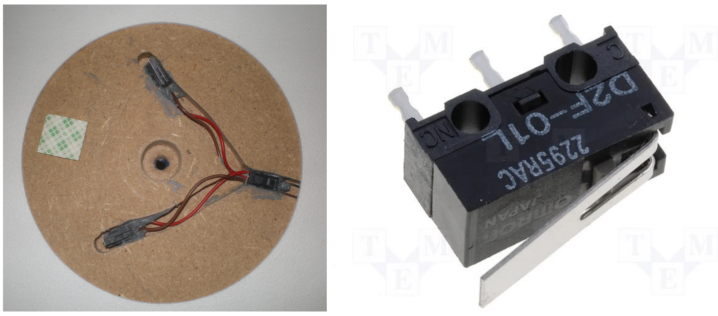
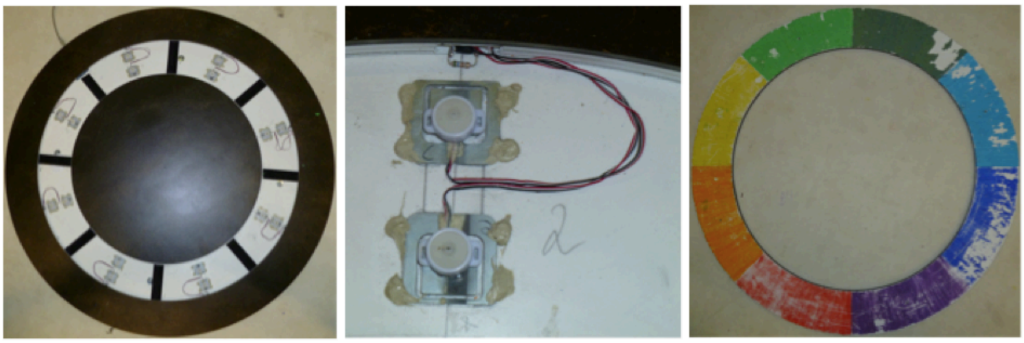


Figure 5.15. Monostable switches of the second proto-type. Each of the twelve colours could be triggered on the basis of three combined switches.

The third prototype of the colour mat was upgraded in two important ways. First, pressure sensitivity was added. This was done by spreading eight pairs of load cells (see Figure 5.16a-b), i.e. an electronic sensor that converts weight into an electrical signal, in order to create a configuration of eight Wheatstone bridges. The variations in voltage are read out and send to a software module that transforms the measurements into a visual effect according to the mapping of the system. Second, it became possible to change the colour circle (see Figure 5.16c). This way, different colour combinations can be used in function of the learning content.



a b c

Figure 5.16. The colour mat of the third prototype used a configuration of eight Wheatstone bridges (a, b), that were connected with a replaceable colour circle.

5.3.3. Control Interface

In the first and second prototype, the mapping from sound and movement to digital painting was a one-to-one mapping (see Figure 5.17).

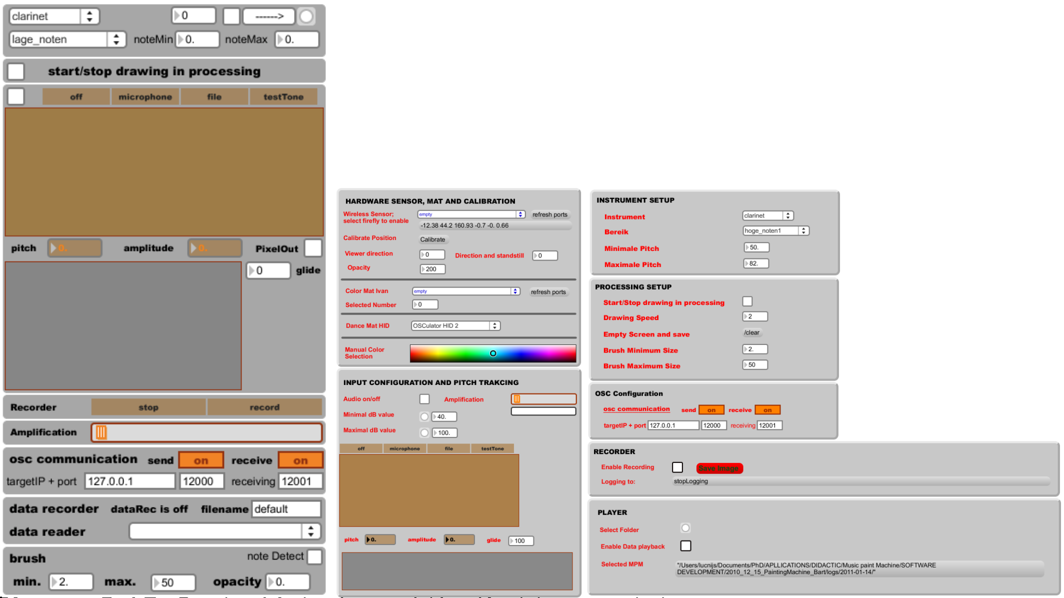


Figure 5.17. Control interface of the first two prototypes.

In the third prototype, major changes where made in the interface in order to allow for a dynamic and adaptable mapping (see Figure 5.18):

- *mapping are established by connecting input and output on the basis of a grid (A).*
- *different drawing options (e.g. direct, linear, exponential) were added (B)*
- *instruments can be chosen and the register of the instrument can be adapted (C).*
- *different colour circles can be chosen (D).*
- *several submodules allow adapting the range of mapped values by setting minima and maxima of values to be measured (e.g. only send values when above or below a certain value) or of mapped values (E).*
- *the configuration of chosen settings can be stored as a level, allowing the quick activation of certain mappings, values or visualizations (e.g. grid or not).*

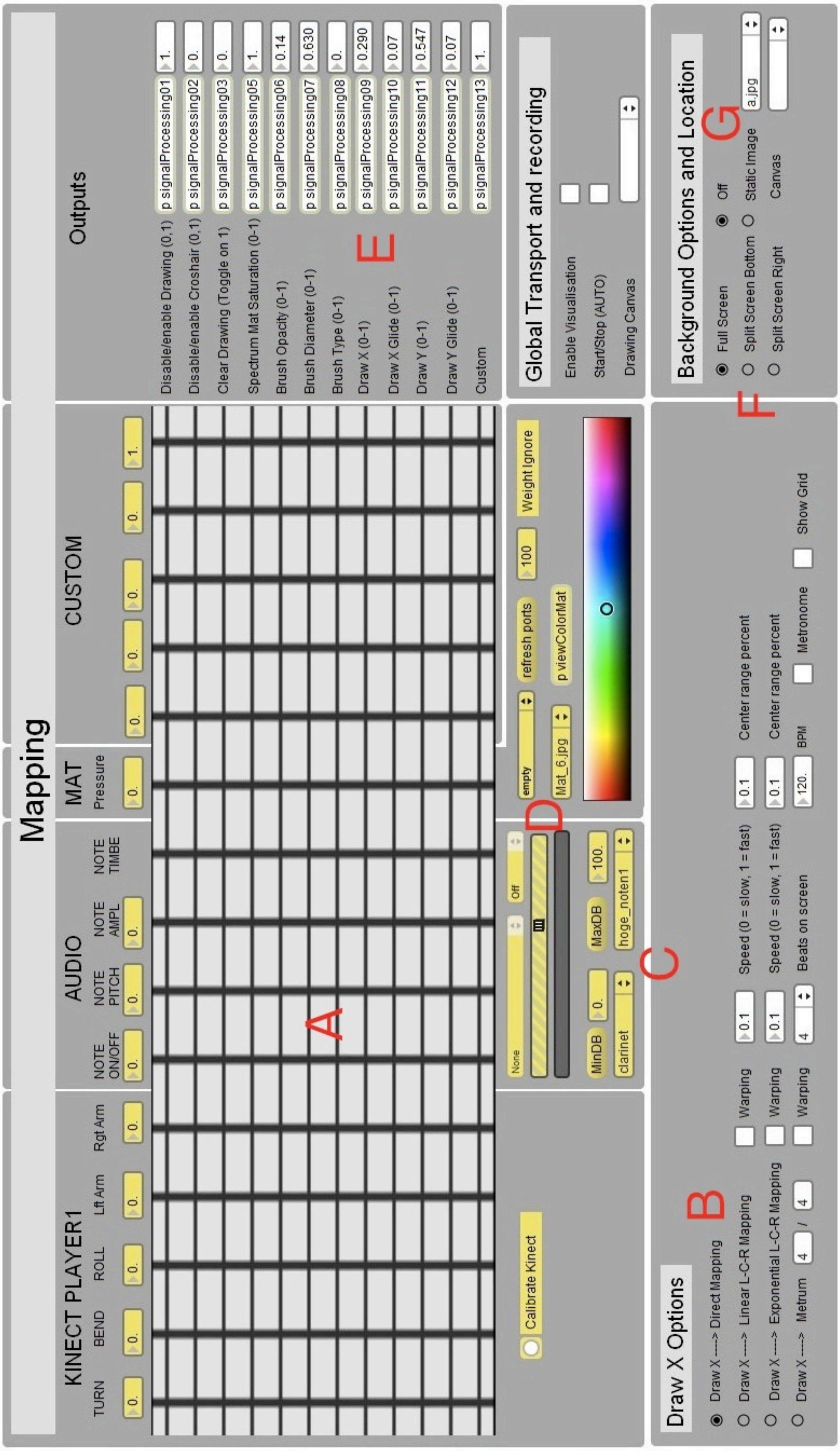


Figure 5.18. Control interface of the third prototype.

5.3.4. Visualization

In the third prototype, major changes where made with regard to the visualization:

- The painting canvas of the system *adapts to the screen* onto which it is dragged. As such, the visualization becomes adaptable to screen size (e.g. computer vs. smart board).

- The canvas can be *split* (horizontally and vertically) to allow a modelling modus. The teacher or a learner makes a painting first and a learner can try to imitate what has been painted (see Figure 5.18 (F) and Figure 5.19).

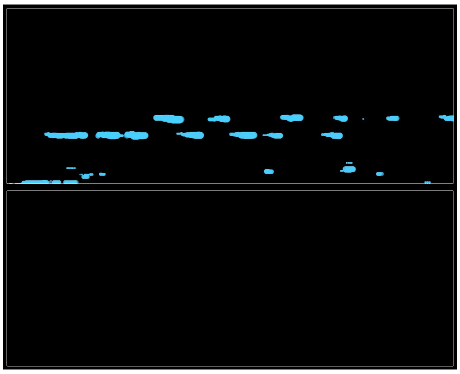


Figure 5.19. Horizontal splitting of the painting canvas (screen).

- Different *backgrounds* can be added. That way it is possible to make models in advance (see Figure 5.18 (G)).

- A *grid modus* was added, allowing the introduction of measure, beats per measure (see Figure 5.20). A metronome can be activated, letting the beat lines of the grid lighten up to show the beats. There is also an option to let the metronome sound.

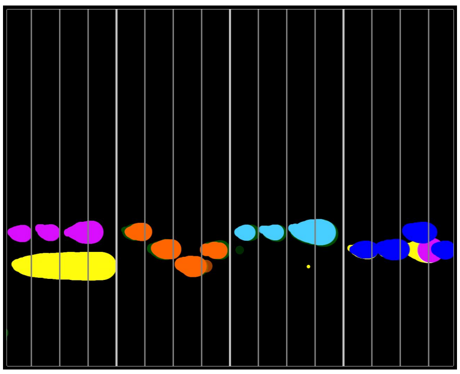


Figure 5.20. A grid can be added to the painting canvas in order to represent beats and measures.

- It became possible to *show the colour circle* in use, in order to indicate people which colour they have chosen (see Figure 5.21).

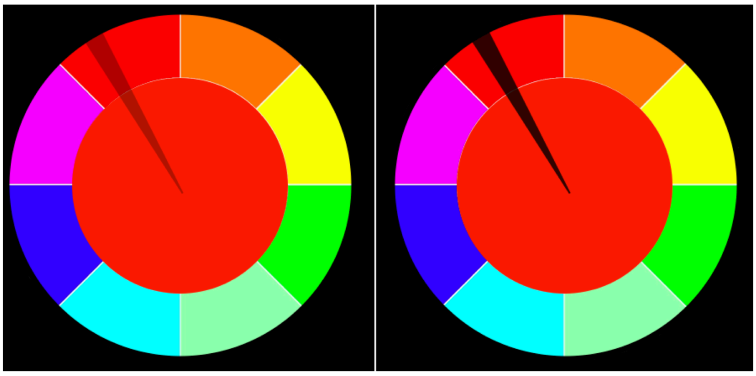


Figure 5.21. A representation of the colour can be displayed on the screen. The chosen colour is displayed in the middle of the colour circle. The arrow points at the chosen colour and provides information on the amount of pressure on the basis of its transparency. Lower pressure leads to more transparency.

- A cursor can be added or left out. The software foresees the future use of *different kind of cursors.*

To conclude, the hardware and software of the Music Paint Machine have undergone major changes since the first prototype. In general, the system evolved towards a highly flexible system that can be tailored to the demands of different situations and practices.

Making these changes aimed at the full realization of the system in agreement with how it was conceived as described in section 5.1. Additionally, changes were based on a user study and in function of a longitudinal study on teaching with the Music Paint Machine. The next part of this thesis elaborated on the empirical framework of these studies.

PART 3: EMPIRICAL FRAMEWORK

CHAPTER 6

The empirical framework: aims and overview

The purpose of this research was to develop an interactive music system that would enable investigating the research question, namely how an interactive music systems can contribute to the development of an embodied understanding of music, when learning how to play a musical instrument. This initial research question lead to three essential elements that needed to be addressed:

- *pedagogical:* what kind of education do we want? Where should it lead the learners?
- *didactical:* how do we try to reach the pedagogical goals? Which methods should we use in instrumental music instruction?
- *technological:* what kind of interactive system do we need? How do we implement the design concept in hard- and software?

These questions were addressed in the previous chapters. In this chapter we elaborate on a fourth element:

- *methodological:* what kind of empirical framework do we need?

The development of the interactive system, the Music Paint Machine, was paralleled by the development of an empirical framework. This was based on an iterative process between (1) a theoretical framework that addresses the pedagogical and didactical elements, (2) a technological framework that addresses the design concept and its implementation in the soft- and hardware, and (3) an experimental framework that enabled to test the system (see Figure 6.1). The development of the Music Paint Machine and its empirical framework involved a 'spiral collaboration' (Addessi & Pachet, 2005) between the researcher and three partners, namely, the designers of the system (concept, software and hardware), the pedagogical experts (learning and teaching), and the users (knowledge and experience).

6.1. Aims of the empirical framework

The rationale that guided the design and development of this empirical framework was the belief that the possible integration of the system in an ecologically valid educational setting is the conditio sine qua non to arrive at a valid scientific investigation. To establish an empirical framework that enables the instructional integration of the system, this research was guided by three objectives. The framework aimed at a research approach that is:

- *driven by pedagogy*
- *connected to the field of practice*
- *focused on the transformative impact of technology*

These three aims guided the iterative process according to which the Music Paint Machine was designed and arrived at its current state.

In the next paragraphs, the aims of the empirical work of this thesis are discussed.

6.1.1 Pedagogy driven

The primary concern of the research presented in this thesis, was the pedagogical relevance of both the Music Paint Machine and the empirical investigations with it. We believe that educational technology research must be driven by pedagogy. Questions related to pedagogical goals and to how these goals can be achieved should precede and underlie conceptual, technological and methodological questions.

Scholars in the field of music education have pointed at different problems with regard to the pedagogical relevance or aims of educational technologies. For example, Hennessy and colleagues (2005) question the nature of technology's potential to challenge traditionalist approaches to music instruction. Beckstead (2001) argues that technology is used to support traditional methods of teaching at the expense of exploring new possibilities. Addessi and colleagues (2004) assert the archaic conception of pedagogical music software and its scarce use in educational settings. According to Manzo (2011), it is a common case that technology dictates instruction instead of instruction dictating the use of technology. As Colpaert says: "the medium makes the method" (Colpaert, 2006). Moreover, Manzo (2011) questions whether new applications are really supporting the teaching and learning process on a long term notice or whether they merely provide fun and short term experiences that lack a pedagogical ground but appeal to young people because of their being "trendy and gimmicky" and having a strong "ooh whow" factor.

In agreement with Addessi and colleagues (2004), we believe that these problems might be related to the way technological applications are designed and to the assumptions or beliefs that underlie the design process. Driven by the seemingly unlimited possibilities of diverse technologies (e.g. motion sensors) or software platforms, a myriad of technological applications are designed to support teaching and learning. One might ask the question whether these applications are based on pedagogic and didactic insights that emerge from the experience with the daily practice of teaching or whether they are mostly inspired by anecdotal experiences and celebrating the endless possibilities of new technologies. In line with the observations of Amiel and Reeves (2008) in the domain of web-based education, one might argue that the development of educational technologies for music tends to be more concerned with the possibilities of using new technologies such as the Ipod, Kinect or custom designed sensors, than seriously considering its pedagogic aims. In line with the observations of Colpaert (1999) in the domain of online language teaching and learning, one might argue that sometimes self-proclaimed pedagogy-driven approaches are rather affordance-driven (shifting the focus from an artifact's functions to the affordances which nudge users to achieve a function) and even disguised technology-driven approach. Relying on a naive believe in the effectiveness of such educational technologies, these applications are conceived as a technological solution to a pedagogical problem that is envisioned by the external technocrat, i.e. the researcher (Amiel & Reeves, 2008; Biesta, 2007). Furthermore, by exploiting these possibilities the technological applications often have a high-tech character. Despite the efforts to create user-friendly interfaces and to use unobtrusive sensing technologies, they remain far from being the plug and play device that teachers can easily use in the classroom. Consequently, many applications do not find their way to the real-life music classroom, but remain the subject of short-term research projects, involving few teachers and learners (see section 4.1).

We believe that the design of educational technologies and the related empirical research is often characterized by an unbalanced equilibrium between the technical and pedagogical considerations and that the design of applications and the accompanying research is often rather technology-driven. To realize a pedagogy driven approach, the iterative process that shaped the design and development of the Music Paint Machine and that supported the empirical framework was continually informed by pedagogical reasoning, based on the theoretical frameworks of constructivism and embodied music cognition (see Chapter 3). Furthermore, the research presented in this thesis aimed at involving teachers and learners and at a long-term investigation of the system's didactic potential to support the development of an embodied understanding of music. This way the pedagogical-theoretical grounding of the design and the research could be complemented with a user-oriented (see Chapter 8) and practice-based (see Chapter 10) approach that appeals to the second aim of the empirical framework, namely the connectedness with the field of practice. This is discussed in the next section.

6.1.2. Connected to the field of practice

Bearing in mind the necessity of integrating the system in a real-life education setting, an important concern of this research was the connectedness to the reality of daily instrumental music instruction.

In the literature on music education research, scholars regularly point at a difficult relationship or even gap between the domain of academic research and the music education practice community (Coffman, 2011; Colwell, 2010; Reimer, 1992; Roberts, 1994; G. F. Welch, 2009). This difficult relationship appears to be twofold.

On the one hand, for many teachers, research findings are not an easily consulted source of informed practice because the educational research is often inaccessible to teachers (e.g. Heller & O'Connor, 2002; Upitis, 1999) or because teachers are reluctant to academic research due to several misconceptions about it (Woody, 2004).

On the other hand, research makes a rather scant appeal to teachers to be involved in research projects (e.g. Hennessy, 2001). Teachers are more often conceived as participants or consumers and seldom as active partners in the production of research. This might explain existing problems concerning the perceived relevance of ongoing research. For example, Heller & O'Conner (2002) argue that most of the studies carried out by researchers outside the field of music education (e.g. psychologists) seem to ask questions that are beside the point for music educators. These authors even argue that there seems to be little persuasive evidence from research that music teachers can use to help them become more successful teachers. An investigation of the existing literature on the design and use of educational technology for instrumental music education (see section 4.1) clearly shows that rather few empirical studies are based on an elaborated experimental framework in which these systems are extensively tested with several teachers and in a naturalistic setting. Existing studies often describe an allegedly innovative system and its possible use in or outside the classroom but the evaluation of these systems remains limited to proofs of concept or small-scale and short-term experiments within an academic setting.

To close the gap between academic research and the music education practice community, three steps were undertaken in our research. First, it adopted a user-oriented approach. The knowledge and experience of both teachers and learners was acknowledged as an important source of information that could inspire the development of the Music Paint Machine into an application that is relevant for instrumental music instruction. Therefore, the active involvement while using the system as well as the way this involvement was experienced, became objects of study (see Chapter 7 and 8). Furthermore, a pilot study was conducted in which three flute teachers individually tested the system and designed and gave a workshop with the system. The teachers, completed several questionnaires (e.g. on flow, presence, didactic potential, technology acceptance) and participated in two focus groups. The flute students completed a questionnaire on their experience. Second, this research adopted a practice-based approach. A nine-month longitudinal study was setup in which children learned to play the clarinet with the Music Paint Machine (see Chapter 10). Also the pilot study with the flute teachers and students is an example of the practice-based approach.

Connecting research and practice through an empirical framework and acknowledging the knowledge and experience of teachers and learners as an important source of information leads to a new approach to educational technology research. It takes into account the transformative impact of technology, i.e. the impact of technology on the different components of instruction and on the processes underlying teaching and learning. This is described in the next section.

6.1.3. Focus on the transformative impact of technology

Throughout this research, it gradually became clear that a pedagogy-grounded and practice-based approach to the design of an educational technology such as the Music Paint Machine needs to focus on the transformative impact (effect on teaching and learning processes) of a technology rather than solely researching its amplicative impact (effect on learning outcome).

The naive belief in the seemingly endless possibilities of the technology is related to what one might call an instrumentalist view on educational technology. In this view, technological applications are the mere means to an end (independent set of predefined pedagogical goals or learning outcomes). In other words, pedagogical goals remain the same regardless of the actual use of a technology. It is believed that inserting the technology in existing didactic practices might make these practices more efficient and will have a positive impact by amplifying the learning outcomes. Accordingly, the instrumental view on educational technology influences the design and the way research is conducted (e.g. experimental design)

Technological applications are often designed to render existing practices more efficient (e.g. Mize & Gibbons, 2000). For example, applications that provide real-time visual feedback based on the objective measurement of the learners' performance are believed to make instruction more efficient because the visual feedback is an alternative to the ambiguity of verbal feedback (e.g. Hoppe, et al., 2006; Howard, et al., 2007). Other applications provide an alternative the (aural) modelling of the teacher. Student performances are compared to a pre-defined model by focusing on, for example, the imitation of gestures (Bevilacqua, Rasamimanana, Fléty, Lemouton, & Baschet, 2006), on timing (Brandmeyer, Hoppe, Sadakata, Timmers, & Desain, 2006; Chan, Jones, Scanlon, & Joiner, 2006) or pitch (Welch, et al., 2004).

According to Papert (1987), the "technocratic" thinking of the instrumental view favours empirical studies that adopt a "treatment methodology" in which the technology is conceived as an independent variable that brings about an "amplicative impact" (Kiesler, 1992), i.e. an increased efficiency as reflected in a "better" learning outcome. The impact of the technology is measured by comparing differences in learning outcomes between a treatment group (instruction with the technology) and a control group (instruction without the technology). According to Mize and Gibbons (Mize & Gibbons, 2000) the instrumentalist view leads to a subordinate role of the teachers who are considered end-users, meant to use the results of the research when it is completed (e.g. Amiel & Reeves, 2008; Hennessy, 2001).

In this research, the final goal was initially determined by an instrumental view and accordingly defined in terms of the Music Paint Machine's efficiency. After an initial user study (see Chapter 8), a longitudinal study was setup to develop good practices and to measure the effect of teaching with the system on the children's learning outcomes (see Chapter 10). However, the methodology of this study somehow took the transformative power of the Music Paint Machine into account. Therefore, all lessons of four groups of three children, in total 120 lesson of one hour, were recorded on video in order to enable a future observation study in which the behaviour of the teacher and the learners and their interaction are analyzed. Also all children completed a questionnaire on their classroom experience after each lesson (see Chapter 10).

6.2. Empirical studies

6.2.1. User Study: Probing the subjective experience when engaging with the Music Paint Machine

In view of the importance of flow experience and its elaboration on the basis of presence (see section 5.1.3), a first study involved probing the subjective experience of teachers and students when engaging with the Music Paint Machine.

To probe the quality of the experience, two questionnaires were used: the Flow State Scale (Jackson & Eklund, 2004) and an in-house designed questionnaire on presence. Chapter 8 reports on this experiment in which 51 amateur musicians participated. The results of this study suggest that the Music Paint Machine has the potential to induce flow.

Next to the quality of the experience when engaging with the system, the evaluation of the didactic potential of the Music Paint Machine was considered an important aspect of the subjective experience of teachers and learners. It was assumed that probing the participants' beliefs about the didactic potential of the system would provide a source of information about the relevance of the system for the daily practice of teaching and learning how to play an instrument. The results suggested that teachers and students experience the system as relevant to instrumental teaching and learning.

An important aspect of this user-oriented empirical study was the combination of probing flow and presence. This way it became possible to analyse the results in function of the possible relationship between both concepts. While in the literature on flow and presence both concepts are often related from a theoretical point of view, few studies report on an empirical investigation of this relationship. Chapter 9 reports on this analysis. The original sample of 51 amateur musicians was expanded to 65 musicians. Results showed a significantly strong correlation between flow and presence. Moreover, the scores for presence significantly predicted the Flow State Scale, and explained a significant proportion of variance in the Flow State Scale. Furthermore, many significant associations were found between flow and presence variables, among which the most significant were the strong correlation between the naturalness of using the system and the Flow State Scale and between the feeling of non-mediation and the Flow State Scale.

Although the questionnaire on presence needs to be further developed, we believe it is an important step in developing the necessary tools to investigate the bodily basis of an engagement with tools such as a musical instrument or an interactive music system. Introducing the measuring of presence into the field of embodied music cognition research is a novel and promising approach.

6.2.2. Longitudinal case study: Learning how to play the clarineo with the Music Paint Machine

After the first user tests, major changes were made to the soft- and hardware to prepare the system for its use in an educational setting. We conducted a nine-month longitudinal study in which twelve children (six to eight years old) learned to play the clarineo. Following a non-equivalent control groups design, the instruction of six of the twelve children was supported with the Music Paint Machine. This study aimed at developing good practices with the system and at probing its didactic effectiveness. Several pre-tests were administered to the children and their parents in order to map possible confounding variables such as the children's home musical environment, personality, self-regulation skills and motor capacities. Throughout the year, the children weekly completed a questionnaire on their classroom experience and parents completed a questionnaire on the amount of practice at home. One pre-test related to music aptitude, namely a tonal and rhythmical discrimination test (Gordon, 1986), was administered as pre-test and repeated every three month throughout the study. Chapter 10 reports on the results with regard to the developmental music aptitude of the children. Results did not reveal significant differences between the control and treatment group. However, what became clear throughout the study was the importance of the transformative impact of the technology. On the basis of this study, insights were gained with regard to methodology that are important for conducting future studies on educational technologies. The transformative impact of an educational technology questions the use of a "treatment methodology" in which the technology is considered an independent variable. Future work on the basis of the collected data might reveal important aspects of this transformative impact on the different components of instrumental music instruction as described in the first chapter of this thesis.

These insights have led to the setup of a pilot study in to the last trimester of the longitudinal study. Conducting this pilot study contributed significantly to this thesis. Therefore, we describe it briefly in the next section. Analysis is currently ongoing.

6.2.3. Case study: The instructional integration of the Music Paint Machine

To investigate the transformative impact of the technology on the teacher's didactic practices, a pilot case study was set up. Three experienced flute teachers volunteered to participate in an experiment that comprised of several steps, spread over three months. Table 6.1 presents the different steps and measures.

The first four steps (pre-questionnaire, exploring the system, post-questionnaire, focus group) and the lesson try-out (step 6) took place at the research institute, in a classroom-like studio. The fifth step was undertaken during the teachers' private meetings at their home or in the music school. Step 7 to 9 were done in the music school of the teachers.

Sessions in the research institute and the lesson in the music school were videotaped with two Canon Legria digital cameras and audiotaped with a Zoom H4n. Camera's and audio recorder were placed in a maximally unobtrusive manner in order to avoid a preoccupation with being recorded.

Although it was a pilot study, conducting this experiment has contributed significantly to this thesis. Working together with the three flute teachers, participating in the focus groups and observing the apparent changes in the way the teachers engaged with the system and in the way they thought about technology and didactics, has contributed to gaining insights on doing educational technology research. The method of this experiment will be further refined for future experiments on music technology integration.

Table 6.1. The different steps of the experimental procedure.

STEPS	MEASURED VARIABLES
1. Providing background	- General background - Musical background* - Computer use* - Computer acceptance (Teo, 2009) - Personality (Denissen, Geenen, Van Aken, Gosling, & Potter, 2008)
2. Exploring the Music Paint Machine	
3. Completing questionnaires	- Flow (Jackson & Eklund, 2004) - Presence* - Didactic potential* - Technology acceptance (based on Teo, 2009)
4. Focus group	- Technology integration - Didactic potential
5. Preparing a lesson with the Music Paint Machine	
6. Try-out at the lab	
7. Give the lesson	- Children: classroom experience*
8. Completing a questionnaire	- Technology integration (based on Teo, 2009) - Didactic potential*
9. Focus group	- Technology integration - Didactic potential

* designed in house

CHAPTER 7

The musical instrument as a natural extension of the musician

NIJS, L., M. LESAFFRE & M. LEMAN (in press). The Musical Instrument as a Natural Extension of the Musician. In: Castellengo, M. & Genevois, H. Music and its instruments. Sampzon, Editions Delatour France.

Abstract

Background in Music Performance

The study of music performance is a fast evolving research area. The advent of new technologies and the view on the embodied nature of music cognition (Leman, 2007) have given a major impulse to new empirical studies on the involvement of the human body during music performance. Although the body of literature on the performers instrumental and expressive gestures (Cadoz & Wanderley, 2000; Camurri, De Poli, Leman, & Volpe, 2001) is growing, far less has been written on the musical instrument as an extension of the human body. The latter is considered to be the most natural mediator between subjective experience and physical reality. This extension can become natural, i.e. part of the body, as a result of several processes. Research is needed to address these processes and the way in which the musical instrument influences both the construction and communication of musical meaning.

Background in Philosophy

Analysis of the relationship between musician and musical instrument raises fundamental ontological and epistemological questions. To grasp the full meaning of this relationship, it should be examined from a broader philosophical perspective in which the interaction between musician and musical environment, the nature of human activity, the role of (self-) consciousness and the nature and quality of subjective experience are of central importance.
The philosophical background of the research presented in this paper consists of a combination of ecological philosophy (Hirose, 2002), activity theory (Kaptelinin & Nardi, 2006) and the philosophy of presence (Biocca, 2001).

Aims

This paper aims at gaining a theoretical understanding of the relationship between musician and musical instrument. Thorough knowledge of the nature and value of this relationship will reveal basic components of the embodied interaction during music performance. We develop a conceptual framework that provides an interdisciplinary theoretical basis for future in-depth studies related to ongoing empirical research (e.g. the EmcoMetteca project at IPEM, Ghent University).

Main Contribution

The main contribution of this paper is a refinement of the concept of musical embodiment in two ways. First, concepts from ecological philosophy, activity theory and presence research are used to identify different components of the music performance situation (e.g. musician, instrument, score, audience, room...) and to clarify their mutual interaction. Second, the study of a non-verbal (social and technology related) communication domain as a concrete example of embodied interaction will contribute to the refinement of philosophical concepts (such as the second-person perspective in music performance, the instrument as mediator, the coupling of action and perception).
The starting point of the presented research is a finding that is shared and intuitively apprehended by many musicians, namely the experience that the musical instrument has become part of the body. We support to the viewpoint that this awareness is a necessary condition for a fine-grained expressive communication of musical meaning.
In this paper it is argued that a symbiosis between musician and musical instrument results from a growing integration of instrumental and interpretative movements into a coherent whole that is compatible with the body of the musician and with the movement repertoire of daily life. Such integration leads to the transparency of the musical instrument that just like "natural" body parts disappears from consciousness. The musical instrument has then become part of the body as stable background of every human experience and is no longer an obstacle to an embodied interaction with the music. It has become a natural extension of the musician, thus allowing a spontaneous corporeal articulation of the music.

Implications

A further elaborated theoretical framework for embodied music cognition will give empirical research a firm ontological and epistemological ground. This is linked up with modern philosophical approaches that go beyond the Cartesian dualism. Research into embodied music cognition is of particularly interesting for the development of interactive multimedia platforms, music education, applications in rehabilitation and numerousof applications within the cultural and creative sector (e.g. for music gaming).

7.1. Introduction

Music performance is recognized as one of the most complex human activities, pushing performers beyond the boundaries of their bodily and cognitive capacities. The study of this interesting human phenomenon is a fast evolving research area. The advent of new technologies and the understanding of the embodied nature of music cognition (Leman, 2007) have given a major impulse towards new empirical studies about the involvement of the human body during music performance. Although the body of literature on the performers instrumental and expressive gestures (e.g. Cadoz & Wanderley, 2000; Camurri, et al., 2001; De Poli, 2004) is growing, far less has been written on the musical instrument as an extension of the human body. Research is needed that reveals the underlying processes of the relationship between musician and musical instrument by investigating the way in which the musical instrument influences both the construction and communication of musical meaning.

This paper aims to contribute to the theoretical understanding of the relationship between musician and musical instrument. Analysis of this relationship raises fundamental ontological and epistemological questions. To grasp its full meaning, it should be considered from a broader philosophical perspective in which the interaction between musician and musical environment, the nature of human activity, and the quality of subjective experience are addressed.

The structure of this paper is as follows: in the next section (7.2) we first outline our approach. The three following sections consider the pillars of the framework. First we elaborate the role of the relationship between musician and musical instrument for the musician's interaction with the musical environment (section 7.3). Then we consider the influence of this relationship on the actions of the musician (section 7.4). In the next section (7.5) we look into the subjective experience of the musician and how it relates to the musician-instrument relationship. Finally (section 7.6) a conclusion is formulated regarding the proposed framework, followed by some remarks on the need for further research (section 7.7).

7.2. Approach

In this theoretical study, we focus on expert music performance in the tradition of Western classical music. We start from a performance situation in which a professional musician performs a composition from notation. Furthermore we consider only instrumental music in order not to complicate things unnecessarily by the presence of language and content in vocal music. We stress the "performing" element, being distinguished by its occasional and ritual character from mere "playing" (Godlovitch, 1998).

The starting point of the presented research is a finding that is intuitively apprehended by many musicians, namely the experience that the musical instrument has become part of the body. We support the opinion that this awareness is the result of an embodied experience that is rooted in an optimal relationship between musician and musical instrument. Moreover we consider it a necessary condition for a flexible and spontaneous expression of artistic ideas (Leman, 2007).

In our framework the relationship between musician and musical instrument is approached from three different but strongly related viewpoints: the musician-instrument connection

1. determines the interaction process between the musician and the musical environment that is created throughout performance.
2. regulates the goal-directed activity structure of music performance.
3. is closely related to the musician's subjective experience during performance.

These viewpoints are elaborated within the framework of the embodied music cognition research (Leman, 2007), based on three philosophical frameworks (see Figure 7.1):

1. *Ecological Philosophy*: the study of relationships between subject and environment
2. *Activity Theory*: a conceptual framework based on six principles (i.e. merging of activity and consciousness, goal-directedness, hierarchic activity structure, mediation, internalization and externalization, continuous development)
3. *Flow and Presence Research*: the psychology of optimal experience.

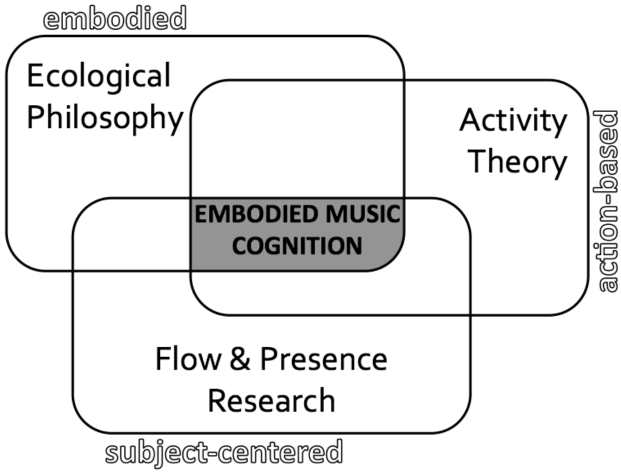


Figure 7.1. Structure of the theoretical background.

7.3. The merging of musician and musical instrument

The merging of musician and musical instrument implies that the musician no longer experiences a boundary between himself and the instrument. The instrument is felt from within and has become like an organic component of the body (Nosulenko, Barabanshikov, Brushlinsky, & Rabardel, 2005; Zinchenko, 1996). This means that the musical instrument is integrated in the bodily coordination system. Instrument specific movements become constituents of the dynamic structure of the body (*body schema*) and thereby part of the somatic know-how of the musician (Baber, 2003; Behnke, 1989). As a result material, functional and formal features of the musical instrument no longer require to be explicitly represented and the musical instrument becomes relationally and functionally transparent in use (Rabardel, 1995). The relational transparency implies that the musical instrument does not interfere with the direct perception of the musical environment. The functional transparency makes the musician feel that he is responding directly to the musical environment, that is without cognitive reflection and solely relying on acquired skills.

Direct perception (clear feedback) and skill-based playing (clear goals) are intrinsically linked to each other and based on a balance between the skills of the musician and the challenges he finds in the musical environment. Thereby all the necessary conditions are fulfilled for the musician to have an optimal subjective experience or so called flow experience while performing.

In the next sections direct perception, skill-based playing and flow experience are elaborated upon with regard to the relationship between musician and musical instrument.

7.4. Direct perception of the musical environment

Music performance entails a series of perceptually guided actions that are embedded in a whole of specific physical and cultural elements such as cultural and musical traditions, the specific configuration of the performance situation and personal characteristics of the musician (Bourgeau, 2006; Essl & O'modhrain, 2006). These elements give rise to the constraints and possibilities of the musical environment that is created during the performance. Because of the specific timeframe of music performance, it is impossible to take every action or its result into account as if it was a perceptually distinct unit. Therefore the musician must be able to pick up information without the need for cognitive processes (*direct perception*) and act directly in attunement with the environment (*body schematic acting*).

The direct perception of the musician can be defined as a bias to perceive the music performance situation in terms of affordances (Leman, 2007). Affordances are elements of the musical environment that capture the musician’s attention by standing out as figure to background. As the expression of action-perception couplings they invite the musician to act according to the coupling between motor trajectories and sensory information (see Figure 7.2).

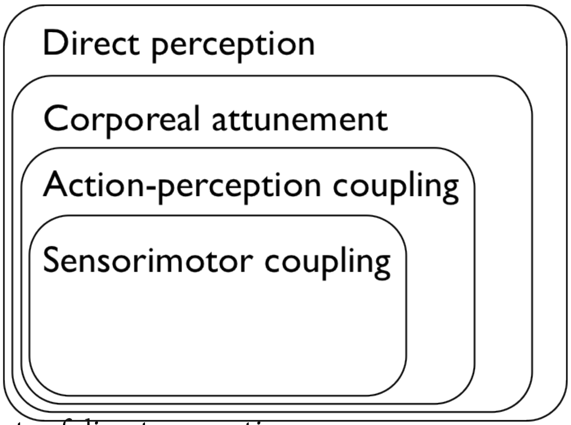


Figure 7.2. The roots of direct perception.

In music performance the affordances are first of all the performance cues. These are orientation points that trigger executive, interpretative or expressive actions as stored in memory during rehearsal (Chaffin, Lisboa, Logan, & Begosh, 2009). Although performance cues are the result of a carefully prepared action plan, they are neither absolute determinants of the performance nor the constituents of an obligatory performance algorithm. As a result of the interaction during performance new elements come to the foreground and create new affordances to which the musician can respond. On the one hand, these new affordances arise due to changes in the constituents of the musical performance situation. Inspired by for example the atmosphere in the concert hall or the interaction with the public, new interpretative elements can come up and invite the musician to realize them. On the other hand they can be the result of sudden insights that pop up during performance.

Affordances have their counterpart in the *effectivities* of the musician (Hirose, 2002). Whether the affordances are perceived, selected and processed in order to guide or even change the way of performing depends on the embodiment of knowledge, skills and experience. When these are incorporated in the body schema, the musician can engage in an embodied interaction with the music and act body schematically, that is automatically select and generate the appropriate responses to the (new) elements that capture attention (Dohn, 2002; Friberg, Bresin, & Sundberg, 2006).

It is important that the musical instrument does not restrain a direct engagement with the music. Only then the musician can freely resonate with the music and respond continuously in a body schematic way to the inspiration of the moment or the constraints that arise from the complex interaction within the music performance situation. Therefore the musical instrument must be incorporated in the body schema. This is possible because the physical body and the body schema do not necessarily coincide (Clark, 2007; Holmes & Spence, 2004; Loomis, 1992; Maravita & Iriki, 2004).

7.5. Music performance as skill-based activity

Mastering the musical instrument implies its incorporation in the musician's body so he can be focused on the musical goal rather than on the technicalities of playing the instrument (Leman, 2007). The high-level skills of the musician allow a fine-grained control over the music performance and prevent the musical instrument from standing in between what the musician wants and what he gets. This means that the goal-directedness of music performance, the way the musician's actions are structured and the mediated character of the musical performance are intrinsically related. To analyze the goal-directedness, the structure and the mediated character of music performance we rely on Activity Theory.

Although Activity Theory has been used by many researchers, the field of music research seems not to be familiar with it. Except for a few exceptions (Burnard & Younker, 2008; G. Welch, 2009; Welch, 2007) we found no literature using Activity Theory to investigate music performance. Yet there are some essential parallels between Activity Theory and the embodied music cognition framework such as the action orientedness, the importance of the subjective experience and mediation. Therefore a combination of both frameworks can contribute to their further refinement.

Rather than being a theory Activity Theory is a set of principles that provide a conceptual framework to approach the interaction between subject and environment (Bedny & Karwowski, 2004; Kaptelinin, 1996a). These principles are (1) the unity of consciousness and activity, (2) object-orientedness, (3) hierarchical structure of an activity, (4) internalization and externalization, (5) mediation and (6) continuous development (Kaptelinin, 1996a; Rabardel & Bourmaud, 2003). It is beyond the scope of this article to elaborate on all these principles with regard to music performance. Therefore we will focus on the most relevant principles: object-orientedness, hierarchic structure and mediation.

7.5.1. The object-orientedness of music performance

According to Activity Theory every human action is directed towards an *Object*. This is the imagined result of a future activity (Bedny, Karwowski, & Bedny, 2001). An activity consists of the transformation of its *Object* in an actual outcome. The motivation to act comes from the coupling of the object to a certain need (Bedny & Karwowski, 2004). This coupling regulates the dynamics of perceptual and cognitive processes and their interaction during performance by determining the musician's perceptive selection, attention and memory retrieval (Nardi, 1996).

With regard to music performance we consider this *Object* to be the inner model of the music that the musician has constructed on the basis of deliberate practice and former experiences. This model gives rise to a set of executive and interpretative/expressive goals that find their expression in the basic, interpretative, structural and expressive performance cues (Chaffin & Logan, 2006). According to the focus of the musician his predefined goals are structured into a hierarchy of conscious *goals* and an unconscious *orienting basis*. The conscious goals are concrete anticipations of future results of the actions during performance, the orienting basis is a set of expectations established through experience (Bardram, 1997).

The hierarchical structure of goals and orienting basis is dynamic. Because of the situated nature of music performance, new constraints and affordances can always arise. As a result it is possible that predefined goals need to be adapted or even transformed (Bedny & Harris, 2005).

7.5.2. Music performance as a hierarchically structured activity

The hierarchy of goals and orientations gives rise to a hierarchical structure of conscious and unconscious actions (see Figure 7.3). Activity Theory makes a distinction between *actions* and *operations*. Actions are conscious goal-directed processes that are planned and performed with conscious thought and attempt to fulfil the objective of the activity (Karpatschof, 2006; Riva, 2005). Operations are actions that became routinized and unconscious through practice (Riva, 2005). They are always related to the object and goals of the activity and therefore controlled by the conditions in which the goal is presented [34]. The hierarchic structure is not static. Depending on the goals that are consciously pursued, operations can become actions and vice versa.

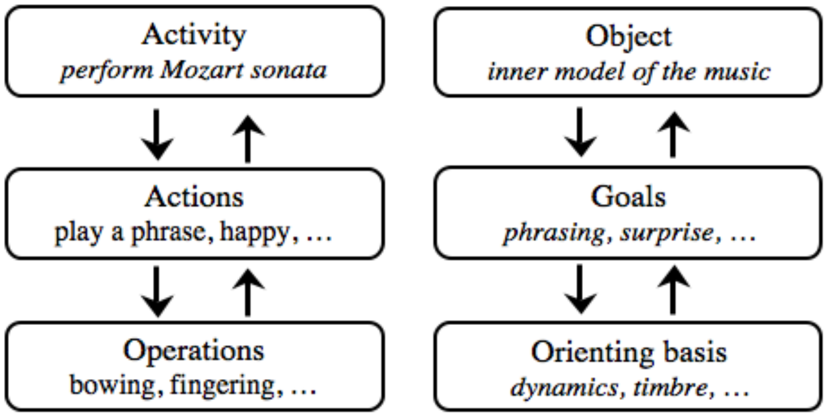


Figure 7.3. The dynamic hierarchical structure of music performance.

When considering music performance, operations are of particular interest. Music performance consists to a large degree of a stable basis that results from deliberate practice. The musician constructs the necessary motor trajectories to be able to play the music. Expert musician's can rely on a large repertoire of automatized subroutines (e.g. chords, scales, articulations) but some passages have to be practiced extensively. Both subroutines and well-practiced passages lead to motor trajectories that can be triggered during performance by the performance cues without the need for conscious reflection. Planning the performance influences the teleological structure of the activity through the hierarchical ordering of the performance cues in accordance with the generic structure of the music (Chaffin & Logan, 2006). Actions that are linked to the basic, interpretative, structural and expressive performance cues become operations by deliberately practicing the executive strategy, i.e. establishing the internal model of the music on the basis of the action reaction cycle (play-listen-judge-change) as put forward by Leman (Leman, 2007). Through the direct perception of these cues the necessary operations are triggered.

7.5.3. Music performance as mediated activity

To communicate his artistic ideas the musician relies upon his instrument. The flexible and spontaneous expression of these ideas depends on the direct perception of the musical environment (section 4) and a skill-based coping with the challenging conditions that arise from the complex interaction during performance.

The mediating position of the musical instrument is grounded in its relation to the activity. According to Activity Theory the mechanism that underlies the mediation is the formation of a functional organ (Kaptelinin, 1996a). This entails the establishment of an intimate relationship between musician and instrument during which both are no longer separated but become a whole in which the sum is more than the parts (Fels, 2000). In the next two paragraphs we first consider the mental level of the musician-instrument connection and second the physical coupling.

Instrumental genesis: the musical instrument as functional organ

The dialectic process that leads to the intimate relationship between musician and instrument is called "instrumental genesis" (Trouche, 2004). It involves the transformation of the musical instrument as a mere material artefact into an "instrument" that is a "functionally integrated, goal-oriented configuration of internal [musician] and external [musical artifact] resources" (Kaptelinin, 1996a).

Instrumental genesis is a twofold process in which the reciprocal influence of musician and musical instrument is reflected. On the one hand the musician influences the musical instrument (*instrumentalization*). According to his needs he will attribute specific functions to the instrument. Moreover a musician always seeks to perfect his instrument by making material adaptations (e.g. by choosing strings, reeds, ligatures). On the other hand the musical instrument has an impact on the musician (*instrumentation*) through the cognitive structuring of the his involvement during performance (Vérillon & Andreucci, 2005). The necessary skills to play the instrument are developed by establishing new or adapting existing mental schemes. These are specialized subsystems that realize a tight action-perception coupling (Pezzulo & Castelfranchi, 2007).

A complex activity as musical performance implies many different schemes that are coupled with the hierarchic structure of music performance. Their degree of activation depends on the specific configuration of the structure. The instrumental actions of the musician are performed on the basis of utilization schemes that contain the predefined structure of consecutive *operations*, the representation of the *object* (inner model of the music) and the music performance situation (Rabardel & Beguin, 2005). They are easily triggered and thereby contribute to the skill-based playing. As such they are an important part of the musician's *orienting basis*. Utilization schemes can be subdivided in *usage schemes* and *instrument mediated action schemes*. The former are determined by the possibilities and constraints of the musical instrument (Trouche, 2004) and are related to the *instrumental signals*, i.e. the feedback given by the instrument. These schemes are responsible for the integration of the instrument related movements in the coordination system of the musician's body and the resulting geometrical match between musician and instrument (see section 7.3). Instrument mediated action schemes focus on the transformation of the *Object* and related to the *non-instrumental signals*, i.e. feedback from the sounding music. They allow the musician to generate automatic responses to elements within the musical environment.

Instrumental genesis is the process that leads to the expertise of the musician by establishing a relationship of reciprocal affordances (see Figure 7.4).

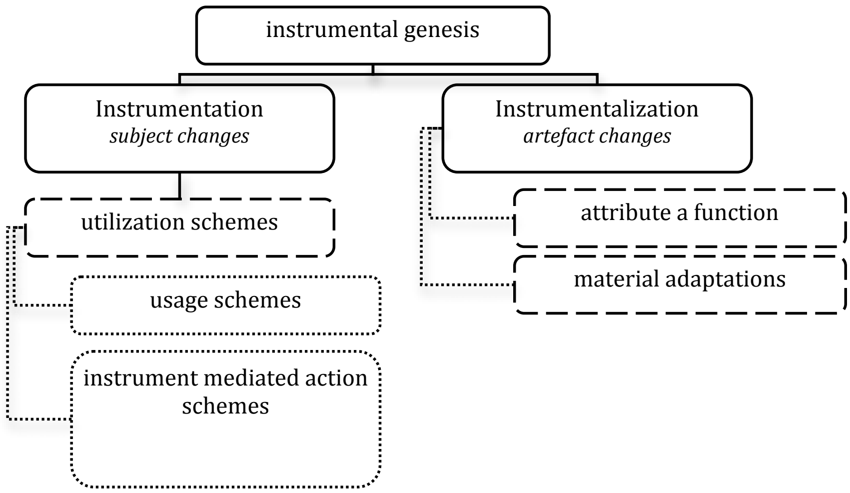


Figure 7.4. The process of instrumental genesis, a bi-directional process in which musician and instrument influence each other.

The artefact enables utilization schemes, the schemes enable the artefact to become functionally integrated in the activity (Rabardel, 2001). Through the combination of instrumentation and instrumentalization the match between the musician's skills and the possibilities the instrument offers becomes consolidated. Throughout years of extensive training (Ericsson, 2003) an expert musician has developed a toolbox of utilization schemes from which he can select the necessary actions to creatively cope with the musical environment he creates during his performance. What he wants is what he gets. The musical instrument has become a functional organ or in other words: a natural extension of the musician (Trouche, 2004).

The physical coupling between musician and instrument

Starting from an embodied framework means acknowledging that the body is the primary and the most natural mediator between the musician's subjective experience and the musical environment (Leman, 2007). What the musician perceives is mirrored in his action-oriented ontology. The information stream that is picked up is disambiguated into an ontology of action relevant cues. This action-oriented bias is reflected in the corporeal articulations of the musician that are translated with the instrument into the sounding music.

When a musician plays an instrument it becomes attached to the body and this has a major influence on the mediating role of the body. The instruments *modalities of existence* (material characteristics), *finalization constraints* (functional aspects) and *action pre-structuring constraints* (regulation of actions) require a specific posture and movements that limit the musician's freedom to move (Rabardel & Beguin, 2005). Posture and technical movement are not always in line with the movements the music suggests. Therefore the musical instrument can block the process of corporeal articulation by restraining the body's motility (Davidson & Correia, 2002). In this way the musical instrument can interfere with the body's natural mediating role. Therefore it is important that the instrument is incorporated in the body as the stable background of the musician's experience.

7.6. The musician in a flow state

The musician's intuitive understanding of being fused with his musical instrument is grounded in a specific subjective experience often referred to as flow experience. This is an optimal experience that can be defined as "*a holistic sensation that people feel when they act with total involvement*" (Csikszentmihalyi, 1990). When a musician experiences flow, he is completely and from moment to moment involved in his playing, functioning at the highest capacity (Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005).

The occurrence of flow depends on the presence of certain conditions (antecedents). These are (1) a balance between the skills of the musician and the challenges posed by the performance, (2) clear goals every step of the way and (3) immediate and unambiguous feedback (Chen, et al., 1999). Once these conditions are fulfilled and the musician does actually experiences flow, his subjective experience is characterized by (1) the merging of activity and awareness (2) complete concentration on the task at hand, (3) a sense of potential control, (4) a loss of self-consciousness and (5) an altered sense of time (Chen, et al., 1999; Csikszentmihalyi, 1990; Custodero, 2005).

Flow experience has a deep impact on the musician. First, it stimulates enjoyment and thereby contributes to a feeling of personal engagement with the activity. It contributes to an intrinsic motivation and to the personal and artistic development of the musician. Second, flow stimulates an implicit learning process. A deeper assimilation of the experience into the embodied background knowledge is established (Dohn, 2002, 2006). This has major implications for the relationship between musician and musical instrument. Every time a musician experiences flow, the musical instrument becomes transparent and temporally a natural extension of the body. In the beginning such an optimal experience will only have a short-term effect on the relationship between musician and musical instrument. But the repeated experience will render the mental schemes that accompany the feeling of having merged with the musical instrument permanent. This results in a long-term intuition, even when the instrument is not at hand.

Although activities in which a flow experience occurs are most of the time mediated by a material artefact (e.g. computer, musical instrument), the vast literature on flow experience shows a considerable lack of attention to the role of these artefacts (Finneran & Zhang, 2003). The focus is mainly on the flow experience itself (most of the time in the context of education) and researchers assume a priori a balance between skills and challenges since this is a necessary condition of the flow experience. But this balance depends mainly on the relationship between musician and musical instrument and therefore the mediated character of musical performance should be taken into careful consideration.

Another element that has not received much attention in flow research is the role of the body. Music performance and in particular playing a musical instrument are to a large extent a corporeal activity. Although some authors mention a difference in the quality of movements during a flow experience, both the degree to which bodily involvement contributes to the flow experience and the way flow experience is reflected (and therefore measurable) in body posture and movements has not been thoroughly investigated (Custodero, 2005; Leman, Desmet, Styns, Van Noorden, & Moelants, 2009).

Our theoretical framework deals with these shortcomings (less attention to mediation and the body) by linking the concept of “presence” and “social presence” to the concept of flow experience. Riva et al. (2004) define flow as a combination of the highest level of presence (*presence-as-feeling*) and a positive emotional state. Presence is defined as *the feeling of being and acting in a world outside us* (Riva, 2008a). Social Presence is the capacity to recognize another subject as intentional (Riva, 2006).

Introducing the concept of social presence contributes significantly to an elaboration of the second person perspective within the embodied music cognition paradigm (Leman, 2007). Within this paradigm the possibility to attribute a second person status to music is considered to be an important way to understand music through the process of corporeal articulation of the moving sonic forms (*corporeal intentionality*).

Although the concept of flow is quite well-known in the field of music[3], the concepts of presence and social-presence have – to our knowledge – never before been elaborated upon thoroughly within the field of music performance research.

7.6.1. Flow, presence and engagement

The relationship between musician and musical instrument is a determining factor in the degree to which the musician's interaction with the musical environment is embodied. For this relationship to be optimal it must allow a direct and engaged interaction with the musical environment (Dourish, 2004). The directness of the interaction depends on direct perception (see section 4) and skill-based playing (see section 7.5).

Engagement is related to the immersion of the musician in the activity of performing. According to Custodero (2005) musical engagement is initiated & maintained through skilled awareness of and responsiveness to opportunities for increased complexity implicit in the musical material. Skilled awareness reflects the complementary relation between the musician's *effectivities* (skills) and the *affordances* and *constraints* of the musical environment (awareness). The responsiveness depends on the musician's skills. Expertise implies an optimal responsiveness. The expert musician has built up an extensive toolbox (Friberg, et al., 2006) of utilization schemes from which he can unconsciously select and execute the appropriate responses to the challenges provided by the musical environment. Finally the increased complexity of the musical material has to do with the ambiguous character of the music and with the situated nature of music performance. Both lead to an interpretative margin that, as an open space of possibilities, invites the musician to push performance to the limits of his abilities.

According to Brown and Cairns (2004) there are three levels of immersion as a degree of engagement. The first level is the mere engagement based on the accessibility (in accordance with personal preferences) and its challenging nature. When the musician directs attention, time and effort the engagement might be complemented with an emotional involvement. This leads to the second level of immersion, engrossment. Now the emotions are affected and the

[3] Mainly in the field of music education.

musician is increasingly cut off from the world outside the activity. The final stage is complete immersion. All that matters is performing. The musician feels the atmosphere of the performance and is empathically involved with the music (Arsenault, 2005).

Brown and Cairns (E. Brown & Cairns, 2004) acknowledge the similarities between the experiences of complete immersion and flow experience. But although they acknowledge that complete immersion is possibly accompanied by enjoyment, they consider it to be the same as presence. Presence however is a feeling that can be experienced without enjoyment. In line with Takatalo et al (Takatalo, 2002) and Riva et al (Riva, et al., 2004), we consider flow to be the combination of presence and a positive emotional state (see Figure 7.5). Flow cannot be experienced without presence but presence can be experienced without flow. The positive emotional state is related to playfulness, creativity and the potential to be creative (Woszczynski, Roth, & Segars, 2002).

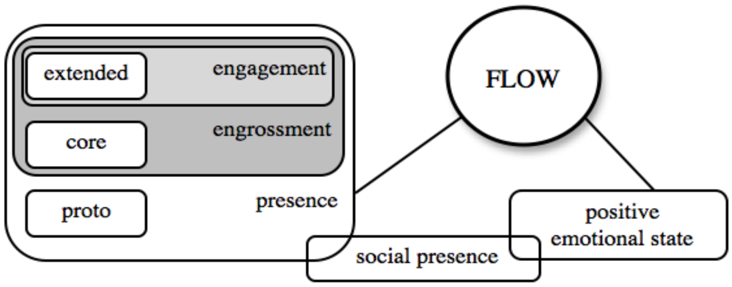


Figure 7.5. The interrelationship of flow, (social) presence and engagement.

7.6.2. Presence and the relationship between musician and musical instrument

If flow cannot be experienced without a sense of presence, then it can only occur when the relationship between musician and musical instrument is characterized by the transparency of the medium. The disappearance of the musical instrument from consciousness enables the musician to be immersed in performing the music. Both transparency and immersion are expressed in the concept of presence when it is interpreted as (1) the feeling of being there, which is intrinsically coupled to (2) the perceptual illusion of non-mediation.

Presence is often defined as the feeling of being present in a world outside us ("there") (Riva, 2008a). This feeling is rooted in a transparent mechanism, denoted as *presence-as-process* (Riva, et al., 2004), that allows controlling behavior on the basis of an unconscious differentiation between the inner and outer world. In music performance the inner world is constituted by the space of motor trajectories, internal thought processes related to the self, and feelings (Leman, 2007; Nideffer, 2002). The outer world is the space of sensory trajectories that arise from the interaction with the music (Leman, 2007). On the basis of this differentiation the musician can monitor whether the result of his actions match his expectations on the basis of predefined and ad hoc adapted goals.

Presence-as-process is situated at different levels, each of which is linked to a level of consciousness (Damasio, 1999). It relies on a coherent collaboration of bodily sensations, perception and cognition to keep attention focused on the activity. The first level, *extended presence*, is cognitive and occurs when the content of consciousness is experienced as meaningful on the basis of intentions, beliefs and personal preferences. The second level, *core presence*, is perceptual. It entails selective attention and is intrinsically coupled to the core affects (Russell, 2003). These are the core of emotions and moods and influence perception, cognition and behavior. The third and most profound level is proto presence. Here the sensorimotor coupling of action and perception coupling plays a defining role. It is about the bodily being in the world. The musician anticipates body schematically and evaluates the action perception coupling. A positive match between efferent (inner world) and afferent (outer world) leads to proto presence. That way presence-as-process unconsciously monitors action and is responsible for the sense of control that is characteristic for flow experience.

A maximal sense of presence, denoted as *presence-as-feeling*, is the feeling of being “there”. Such an experience occurs when the content of every level of consciousness is the same (*focus*) (Waterworth & Waterworth, 2001). Depending on whether all levels of presence are focused on the inner or outer world (*locus*), the attention shifts to the self or the non-self (Nideffer, 2002). Depending on the degree of arousal (*sensus*) attention becomes more focused on a limited set of stimuli (Nideffer, 2002). This implies that presence-as-feeling will always be accompanied by the *perceptual illusion of non-mediation.* When all levels of the musician’s consciousness are being occupied with the sensory trajectories (feedback on the result of playing the instrument, non-instrumental signals, outer world) the motor trajectories (feedback on the technical handling of the musical instrument, instrumental signal, inner world) will not enter consciousness. Accordingly the musical instrument is unconsciously considered as an aspect of the self and this results in the intuitive apprehension of the fusion between musician and musical instrument.

An important aspect of the layered nature of presence is the fact that maximal presence involves the orientedness of the body on the external world. Presence can occur without proto presence but this will not lead to a flow experience, for which maximal presence (presence on the proprioceptive, perceptual and cognitive level) is required. Based on the differentiation between the levels of presence, it can be argued that extended presence is similar to mere engagement, the combination of extended and core presence to engrossment and maximal presence with complete immersion. According to Brown and Cairns (2004) empathy is one of the barriers for presence.

7.6.3. Social Presence: empathy with the music

Empathy is based on an understanding and identification but is also characterized by detachment in order to differentiate one's own (self) and the other's (non-self) intentions (Decety & Jackson, 2006). The detached position is based on presence as the mechanism to differentiate self and non-self. The understanding and identification is based on social presence that is defined by Biocca & Nowak (2002) as "*the feeling that one has some level of access or insight into the other's intentional, cognitive, or affective states.*"

Social presence makes the musician conceive of the music as an intentional being or as the mediated embodiment of a person that is virtually present (Biocca & Harms, 2002). This is possible because of *naked intentionality*, the innate capacity to recognize intentions without immediately realizing whose intentions they are and what their content is (Riva, 2006, 2008b). The behavior of the music as a virtual person is suggested by the moving sonic forms (patterns in the sound energy). These are directly perceived in terms of the musician's action oriented ontology. Structural and semantic aspects of the music are translated into the affective, expressive and emotional world of experience of the musician based on the associations with his own movement repertoire (Leman, 2007).

Social presence can be divided into *social presence-as-process* and *social presence-as-feeling*. The latter is a result of the former and entails the direct perception of the intentions. Social presence-as-process is a layered process that varies from the mere awareness of another's presence (*co-presence*) to a more intense feeling of insight in another's intentions. It enables the musician to recognize the music's D-, P- & M-Intentions as proposed by the dynamic theory of intentions (Pacherie, 2006, 2008). D-intentions are the result of a practical reasoning process about goals, means and executive strategies and can easily be linked to the interplay of rational and intuitive analysis that leads to the construction of the inner model of the music. P-intentions guide ongoing actions. While D-intentions concern the goal-motive coupling, P-intentions anchor the musician's actions in the actual performance situation. These intentions constitute the goals that are necessary to achieve the object as overall goal (what?). The M-intentions are responsible for the unconscious directing and monitoring of the activity (how?). These intentions find their expression in the orienting basis. D-, P- and M-Intentions are inextricably and causally coupled to each other in an *intentional cascade*. But not all activities require the conscious presence of the three levels of intentions. Well-prepared or practiced activities like musical performance do not always require online monitoring by the P-intentions. In the case of music performance the P-intentions (*goals*) are integrated in the inner model of the music and thereby unconsciously steer the M-intentions. Accordingly, music performance relies on proto social presence-as-feeling, which is an automatic response to something that moves, namely the music (Biocca & Harms, 2002). This means that the musician can play intuitively or as commonly expressed: "from the gut".

The automatic empathic response is based on the process of corporeal imitation (Leman, 2007). Perceived movements in the music (*moving sonic forms*) are, via the body, turned into action-oriented percepts that are associated with expression. Music performance then is about the expression or articulation of the perceived intentions. This entails the enaction of the recognized intentions. From this viewpoint, the movements that are suggested by the music can be considered as affordances, understood as "invitations to *en*act". The transformation of the perceived intentions into a sonic result is monitored by presence, the latter being conceived of as the non mediated prereflexive perception of the successful transformation of an intention in action within an external world (Riva, 2008a). Presence thus makes social presence possible. Therefore we can conclude that an empathic relationship with the music and its expression on the basis of corporeal engagement is only possible when the performance is characterized by the perceptual illusion of non-mediation.

7.7. Conclusion

In this paper we have approached the relationship between musician and musical instrument from a broad philosophical perspective. By using concepts from ecological philosophy, activity theory and flow/presence research, we have elaborated upon a core idea of the embodied music cognition framework, namely that a fine-grained expressive communication of musical meaning results from an embodied interaction with the music.

In music performance the embodied interaction with the music implies the corporeal attunement of the musician to the sonic event that results from the performance. The embodied experience of participating in the musical environment in a direct and engaged way is based on the direct perception of the musical environment and on a *skill-based* coping with the challenges (*affordances* and *constraints*) that arise from the complex interaction within this musical environment. It becomes an optimal embodied experience (*flow*) when the musician is completely immersed in the created musical reality (*presence*) and enjoys himself through the playfulness of the performance. Therefore direct perception of the musical environment, skill-based playing and flow experience can be conceived of as the basic components of embodied interaction and communication pattern.

From the theoretical elaboration of the relationship between musician and musical instrument we learn that these three components are only possible when the musical instrument disappears from consciousness while performing. The resulting transparency of the musical instrument leads to a short-term intuitive apprehension of being one with the musical instrument. The repeated embodied experience of being merged with the musical instrument leads to the musician's long-term intuitive apprehension that it has become a natural extension. The naturalness of the extension follows from the incorporation of the musical instrument into the body schema. The resulting attuning of the extended body to the musical environment enables the musician to freely and expressively communicate his artistic intentions on the basis of the corporeal articulation of the moving sonic forms. Paraphrasing Yeats[4], we can say that musician and music have become one ...

7.8. Future work

An important aspect of the embodied music cognition research paradigm is the combination of objective and subjective measurement methods. The theoretical elaboration in this paper provides a conceptual framework that will contribute to the further development of these methods. For example the concepts can be used to guide the construction of questionnaires that probe flow and presence. This asks for a further elaboration of the relation between flow and presence.

[4] W.B Yeats. "Among school children"

The elaboration of the three basic components of an embodied interaction with the music can also contribute to the design of new interactive multimedia platforms technologies. Furthermore insights in the process through which the relationship between musician and musical instrument is established, provide a top down strategy for the implementation of an embodied approach to music in instrumental music teaching.

Next to the top down strategies based on the above conceptual framework, an experimental framework needs to be elaborated on the basis of which the conceptual model can be further refined and validated.

CHAPTER 8

The Music Paint Machine: Stimulating Self-monitoring Through the Generation of Creative Visual Output Using a Technology-enhanced Learning Tool

NIJS, L., MOENS, B., LESAFFRE, M. & LEMAN, M. (2012). The Music Paint Machine: stimulating self-monitoring through the generation of creative visual output using a technology-enhanced learning tool. Journal of New Music Research, 41(1), pp. 79-101.

Abstract

In this paper, we discuss the pedagogically grounded and research-based design of a technology-enhanced learning tool, the Music Paint Machine. This interactive music system introduces a musical experience in which the musician creates a digital painting by playing an acoustic musical instrument and by moving the body on a coloured pressure mat. As a learning tool it aims at the development of musical creativity, at the stimulation of embodied understanding of music and at the development of an intimate relationship with the musical instrument.

First, the methodological approach is outlined and pedagogical and theoretical backgrounds are discussed. Then, we report on an experiment in which 51 amateur musicians participated. The experiment aimed at probing the application's potential to induce a flow experience and to learn about how participants evaluate the didactic relevance of the Music Paint Machine. Results suggest that the Music Paint Machine has the potential to evoke a flow experience. Furthermore participants acknowledged its didactic relevance with regard to learning to improvise, to developing understanding of musical parameters and to stimulating creativity.

8.1. Introduction

In this paper, we describe a technology-enhanced music learning tool, called the Music Paint Machine, which provides musicians with visual feedback by monitoring their playing. The system allows a musician to draw a painting on a computer screen by playing a melodic acoustical music instrument (such as clarinet, flute, trumpet, violin, singing, . . .), while moving on a coloured mat. An essential aspect of this learning tool is its embedment in a pedagogical framework that is inspired by recent developments in embodied music cognition.

There are several motivations behind the development of the Music Paint Machine. A first motivation is concerned with the question whether a technology-enhanced educational tool can be developed that facilitates learning how to play a classical musical instrument. We believe that the Music Paint Machine is indeed a step towards such a learning tool, as it tries to stimulate the students' musical creativity and playfulness with musical parameters. Flow, peak, or optimal, experiences have often been acknowledged as fundamental to the development of musical creativity (Csikszentmihalyi, 1990; Addessi & Pachet, 2005). By providing students with an immersive experience of playing with musical parameters, body movements and visualizations, the Music Paint Machine aims at inducing such optimal experiences with hopefully positive effects on musical creativity. In addition to the flow experience, playfulness with musical parameters has often been considered an important aspect of musical creativity as well (e.g. Deliège & Wiggins, 2006). The goal is here to stimulate students to explore and experiment with different musical parameters, using particular learning methods and learning tools. Learning to be playful with musical parameters, using the Music Paint Machine, is thus linked with learning how to improvise. Improvisation can be considered as an essential component in the development of musical creativity (e.g. Van Regenmortel & Strobbe, 2010).

The second motivation is concerned with the question whether a technology-enhanced educational tool can cope with corporeal-based theories of musical meaning formation—as we believe that these theories have a great potential in the field of education. Musical experience, including music performance, is often seen as having a firm and indispensable corporeal ground (e.g. Bowman &

Powell, 2007; Leman, 2007; Godøy & Leman, 2010) and body movement is believed to provide students with a way to fluently access musicality (e.g. Dalcroze, 1980; Pierce, 2007). We believe that technology can stimulate an embodied understanding of musicality by invoking body movement as constitutive to the musical experience and by accommodating to the multi-modal nature of musical experience by means of real-time visual feedback. By using body movements to influence the way musical parameters are visually represented, the Music Paint Machine invites students to explore and experiment with the corporeal dimension of playing music. In this way, it provides them with an experiential basis that might contribute to the musical signification processes. In addition, musical experience is also said to be multi-modal (Leman, 2007). When performing music, the interaction with the performance context (musical instrument, music, audience, concert hall) involves the simultaneous perception of the different sensory modalities and a close interaction of sensory processing with motor production (Lappe, Herholz, Trainor, & Pantev, 2008). The Music Paint Machine aims at enhancing this multi-modal aspect by combining visual feedback with audio input and motion input.

The third motivation is concerned with the question whether a technology-enhanced educational tool can contribute to the establishment of an optimal relationship between the musician and the musical instrument. This question is related to the idea that the unity of musician and musical instrument, or at least the intimate interaction between musician and musical instrument, is an important aspect of musicianship. In an optimal relationship with the musical instrument, the musician is not hindered by the technicalities of handling the instrument so it becomes possible to focus on musical goals and to immerse in the musical world that is being created throughout the playing (Leman, 2007; Nijs, Lesaffre, & Leman, 2009). The Music Paint Machine aims at offering a learning environment in which the relationship between musician and musical instrument can be fully deployed and monitored, through the visual feedback on the screen. This optimal relationship with the musical instrument is assumed to rely on the fine-grained control over the instrument, and for that reason, parameters such as intonation and dynamics can be enhanced and explored. We believe that the study of the effect of technology-enhanced feedback of fine-grained control parameters is educationally appealing in the sense that it may contribute to an efficient learning of advanced musical skills.

The goal of the present paper is to introduce the Music Paint Machine by describing the design of this technology-enhanced learning tool in relation to the educational, cognitive theoretical, and experimental framework. Our approach aims at optimizing the didactic potential of the Music Paint Machine through a ‘spiral collaboration’ (Addessi & Pachet, 2005) between three partners, namely, the designers of the system (who work on the concept, the software and the hardware of the tool), the pedagogical experts (who work on learning and education), and the users (who work with the tool, such as teachers and students). The ultimate purpose of our research is to evaluate if the Music Paint Machine can be effectively used to learn to play music. However, this is a long term goal and this paper, therefore, is limited to a description of the design, the underlying principles, and the results of a first experiment that aimed at probing the Music Paint Machine's potential for inducing a flow experience while playing. Given the user-oriented development approach, we also report briefly on the participants' perception of the didactic potential of the application.

This paper is structured as follows: in a first part, we describe the relationship between the Music Paint Machine and monitoring in music education (Section 2). In the second part, we explain the methodological approach behind the design of this learning tool (Section 3). Next, we outline the background that constitutes its conceptual design (Section 4), which is followed by a description of its implementation in hard- and software (Section 5). The next part (Section 6) describes the setup of a first experiment that was conducted with 51 amateur musicians, followed by a report (Section 7) and discussion (Section 8) of the results of this experiment. Finally, we present the general discussion (Section 9) and a conclusion (Section 10).

8.2. The Music Paint Machine and monitoring

Technology-enhanced learning tools aim at providing solutions to certain problems in education. One of the central issues is concerned with the feeling that education is often a slow process and that the use of tools may perhaps facilitate and speed up the learning process, so that learning becomes more efficient in terms of produced quality in a shorter time span. This idea clearly applies to music education, where learning how to play a musical instrument is known to be a time-consuming and pedagogically intensive process. Does there exist a technology-enhanced learning tool that can make music education more efficient?

A good starting point to tackle this question is to consider the monitoring of a musical performance, in particular monitoring one's own performance, as this may be a crucial aspect of learning how to play a musical instrument. Indeed, self-monitoring implies an awareness and evaluation of the quality of one's own playing, which forms a basis for error correction and further improvement of one's playing skills (Goolsby, 1995; Palmer & Drake, 1997; Woody, 2001; Altenmuller & Gruhn, 2002). However, this awareness and evaluation can interfere with the performance in such a way that it affects concentration, focus, and eventually the musicality of the playing. The question is whether a monitoring tool can help develop this sense of self-monitoring.

In traditional music education, self-monitoring is primarily acquired through a master–apprentice model. In this model, a 'master' or music teacher helps the 'apprentice' or student to develop the necessary monitoring skills by giving verbal and gestural feedback on different aspects of their playing (e.g. posture, technique, interpretation) (Ericsson, 1997; Lehmann, 1997; Hoppe, Sadakata, & Desain, 2006). By receiving repeated feedback from the teacher, the learner gradually develops the self-awareness that is necessary to evaluate his/her own performance quality.

However, recent pedagogical developments propose a constructivist model of education, which is different from the traditional educational model. This constructivist model is based on a learner-centred approach in which decision-making, autonomous self-monitoring and self-regulation are considered to be essential (e.g. Elliott, 1995, 2005). In this approach, exploration and experimentation are promoted as an experiential basis for students' self-learning and development of self-monitoring skills. Consequently, the feedback is less teacher-imposed, and more learner-controlled than the traditional educational model. Educators believe that feedback should include the following characteristics (Bos, 2001):

- *be intrinsic and embedded in the students' performing experience;*
- *be direct and highly responsive and immediate;*
- *maintain engagement and motivation;*
- *present the learner with the opportunity to reflect on it.*

It is important to develop a proper monitoring tool that helps to realize these feedback characteristics. Therefore, what is needed is the development of a proper technology-enhanced learning tool that is fully embedded within the educational context, and that is well grounded in a theory of human–machine interaction. Such a tool should be developed in a context that allows the testing of its effectiveness in music education, so that it is possible to tell whether the tool makes any difference in learning or not.

With the development of the Music Paint Machine and the integration of a monitoring and feedback system we want to complement educational approaches with a technology-enhanced learning tool that (1) makes it possible to monitor different aspects of playing a musical instrument, such as breathing, sound characteristics, posture, bow speed/pressure, using state-of-the-art sensing technologies, (2) stimulates intrinsic feedback mechanisms by providing an immersive experience that engages its users in an interactive feedback loop and stimulates intrinsic motivation, and (3) provides off-line feedback (in the form of paintings and other types of data logs) as pedagogical documentation that can be used for further study and reflection. Accordingly, the application is intended to introduce new ways of monitoring the students' playing that can potentially enhance learning and teaching (Nijs, Coussement, Mü ller, Lesaffre, & Leman, 2010).

The idea that technology-enhanced systems can contribute to monitoring and thus to more effective music education is not entirely new. Reference can be made to previous systems, such as the augmented mirror (Ng et al., 2007) or the 'seeing sound' system of Ferguson, Moere, and Cabrera (2005). The augmented mirror allows the tracking of the bow of the violin and the system can provide an analysis of the playing characteristics, including recommendations for improvement. Ferguson and colleagues developed a system that provides real-time feedback on sound characteristics. The main difference with the augmented mirror is that our approach can be applied to a large range of acoustical musical instruments, and that the processing of audio, motion, and visual information is based on concepts that are rooted in child education, embodied music cognition theory, and conceptions about music mediation. The main difference with the 'seeing sound' system of Ferguson et al. lies in the kind of visual feedback that is provided. The development of the Music Paint Machine is strongly user-driven and based on a close interaction with students and teachers.

8.3. Methodological approach

The design and development of the Music Paint Machine is directed at an optimal embedment of this learning tool within a pedagogical framework and context. This pedagogical embedding is a major concern in ongoing research concerning technology-enhanced music learning (e.g. Webster, 2002, 2007; Adessi & Pachet, 2005; Addessi, Ferrari, Carlotti, & Pachet, 2006; Bresler, 2007). In line with current developments within the field of embodied music cognition (Leman, Lesaffre, Nijs, & Deweppe, 2010) and in music education research (for an overview see e.g. Colwell & Richardson, 2002; Bresler, 2007), we adopt a methodological design approach that copes with three recent developments, namely, (1) a shift of focus from a subject who participates in an experiment to a user of tools, (2) a shift of focus from laboratory research to research in an ecological setting and (3) a shift from a mere qualitative approach to a combination of qualitative and quantitative research methods.

8.3.1 Embedding the Music Paint Machine in a pedagogical context

The pedagogical embedment of the Music Paint Machine implies the participation of active subjects whose actions contribute to relevant output that forms part of our study. Therefore, the active involvement while using specific technology-enhanced learning tools as well as the way this involvement is experienced become objects of the study (Leman et al., 2010). This means that our approach is practice-based and user-oriented in order to ensure the application's relevance within the field of music instrument education. The purpose is to develop didactic practices with the Music Paint Machine, which are based on common findings of students and teachers who used the application. Qualitative methods are here used to analyse the users' experience and the ideas that emerged from this experience (e.g. questionnaires), and as a means to exchange the experiential knowledge (e.g. focus groups). Furthermore, findings from the qualitative approach provide a solid basis for guiding the development of hardware (e.g. a coloured mat that allows the selection of colours for visual feedback) and software (e.g. the mapping of high and low pitch to high and low positions on the visual feedback). The goal is that throughout different developmental and experimental phases, a continual iteration between theory and practice and between research and user feedback is established. This can make sure that the conceptual design and its implementation into the necessary soft- and hardware are continuously informed by pedagogical reasoning. This process will lead to the design of good practices that will be tested empirically. Results will be compared to the theory behind it.

By adopting this design methodology, it is also possible to take into account the particular situation of the so-called part-time music education system, which is a specific form of non-compulsory educational system that is organized in music academies. This education system can be seen as an addition to the regular school education system (Tchernoff, 2007). Children and adults can follow it.

A characteristic aspect of this educational system, when seen in relation to the development of a technology-enhanced learning tool, is the existence of a wide gap between the practically oriented educational goals and the academic world. According to Woody (2001), this gap can be attributed to several misconceptions about academic research that exist among music teachers. For example, it happens that teachers are cautious and even reluctant towards academic research and the use of technology-enhanced learning tools in their proper educational environment. However, we believe that by involving teachers more closely in the design process of a technology-enhanced music-learning tool, it is possible to establish a close collaboration between researchers and teachers. Such an approach is adopted here, as we believe that a user-based development cycle may increase the relevance (ecological validity and impact; see also Welch, 2009) of the Music Paint Machine for music instrument education.

8.3.2 Bringing research into the field of practice

Our design method is largely determined by a gradual shift in focus from a laboratory setting to an educational setting (see also: Addessi & Young, 2009; Ilari & Gluschankof, 2009). An ecological approach of observing users in their habitual environment emphasizes the importance of understanding teachers' and students' concerns about technology-enhanced learning systems. At this early stage of development, a first trial with the use of the Music Paint Machine in an educational context has been conducted in music academies (73% of the tested population), under the guidance from the experimenter, as well as in the laboratory (27% of the tested population). Although this deployment of the Music Paint Machine in music academies is perhaps not yet fully ecological, we believe that the confrontation with context-dependent practical requirements has lead to results that contributed to the further development of the application in terms of its usability.

8.3.3 Combining qualitative and quantitative research methods

The methodological approach is furthermore characterized by a combination of qualitative and quantitative research methods. Traditionally, the effect of music education has been reflected in descriptions based on assessments that involve subjective interpretation. In addition to that approach, the new generation of technology-enhanced learning tools offers means to monitor the students' performance using sensing technologies that provide them with more objective data on, for example, movement and sound. The data are objective in the sense that algorithms can extract higher-level features from the data. These features can provide both teacher and student with useful information when compared with other data (e.g. other students, of the student's learning progress). New technologies thus complement subjective measurement methods (e.g. questionnaires, video annotation, narrative analysis) with objective measurements (e.g. sound and movement analysis) that form part of the technology-enhanced learning tool.

However, to further ensure the relevance and the possible impact of the Music Paint Machine as a usable didactic tool in the field of instrumental music education, we believe that the research method can initially be qualitative. It means that, prior to the quantification of the learning process, it is important to gather and analyse qualitative data on the user experience of students and teachers. Specifically, we believe that answers to open questions in the questionnaire and information retrieved from the focus group can provide us with the necessary information that is needed to optimize soft- and hardware modules of the technological tool. By adopting qualitative methods in a user-oriented approach which is fully embedded in an educational setting, we believe that it is possible to ensure the application's relevance for the naturalistic context and to design didactic practices that are acknowledged as useful for the daily practice of teaching and learning how to play an instrument. Therefore, based on the findings that result from the qualitative approach, decisions will be made to refine the quantitative approach and make sure it leads to findings that are considered relevant for teaching practice.

Given the three characterizations that we described above with regard to our methodology, and how they fit with recent shifts in research attention, it is now possible to present an overview of the design methodology in figure 8.1.

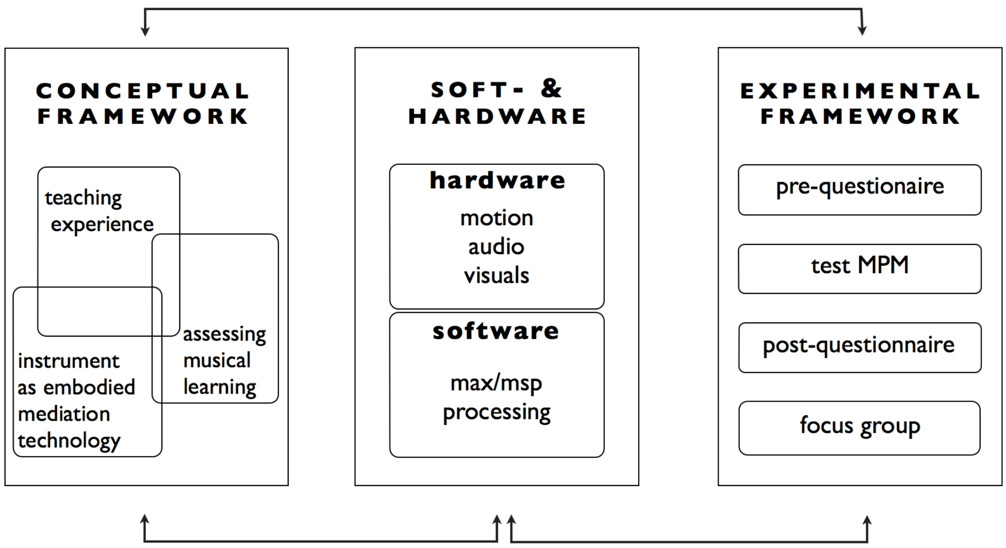


Figure 8.1. Overview of the methodological approach. The concept of the Music Paint Machine is based on a conceptual framework that guided both the design of the system (hard- and software) and the establishment of the empirical framework. The findings from the experiment (e.g. empirical validation of constructs, user feedback) are used to refine the conceptual basis and to adapt the hard- and software in order to optimize the user experience.

The first module and starting point of the methodology is concerned with the conceptual framework that is based on teaching experience, on the musical instrument as embodied mediation technology and on the assessment of musical learning. The core of this framework is the practice of teaching. This aspect will be worked out in Section 4. The second module deals with the development of software and hardware and this will be discussed in Section 5. Finally, there is an experimental framework in which theoretical assumptions are empirically tested and users' experience and evaluation of the didactic potential of the application are probed. This will be dealt with in Section 6.

8.4. Backgrounds and conceptual framework

The conceptual design of the Music Paint Machine is based on three backgrounds, namely, on teaching experience, on a theoretical investigation of the relationship between musician and musical instrument, and on research on assessment in part-time music education.

8.4.1 Daily teaching practice

The concept of the Music Paint Machine is partly influenced by the first author's teaching experience as a clarinet and chamber music teacher in formal music instrument education. His teaching experiences, as well as the questions that arose from the daily interaction with students, were a source of inspiration for two of the Music Paint Machine's essential aspects, namely visual performance feedback and the use of specific body movements.

The potential contribution of visual feedback to the development of a sense of musical feeling, and even the development of listening and playing skills, were first explored in the classroom by using waveform visualization in Audacity (http://audacity.sourceforge.net). It was found that visual feedback can reinforce the verbal and gestural feedback of the teacher by providing images that display information on what the student actually played (as sometimes opposed by what they 'think' of having played). Next to visual feedback, body movements and postures were used to learn specific musical and instrumental aspects of performing. Figure 8.2 shows an example of lateral movements with the instrument and the torso that were used to teach students to feel the timing of musical phrases. Figure 8.3 shows step exercises that were used to teach students to feel the metre of the music with its repetitive pattern of strong and weak beats. Based on this early intuition, it was possible to suggest essential features that a technology-enhanced system for music learning should possess and that could then be further refined and tested. Examples are: the mappings of body movement to a visual parameter, and the round design of the coloured pressure mat.

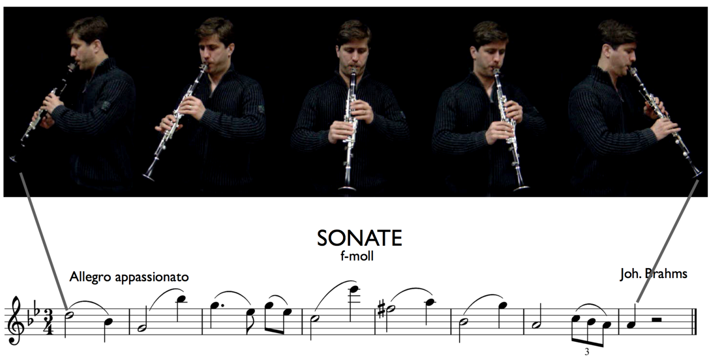


Figure 8.2. Example of a didactic exercise to develop sense of timing: the beginning of the musical phrase is the starting point of a lateral movement that goes from one side of the musician to the other side.

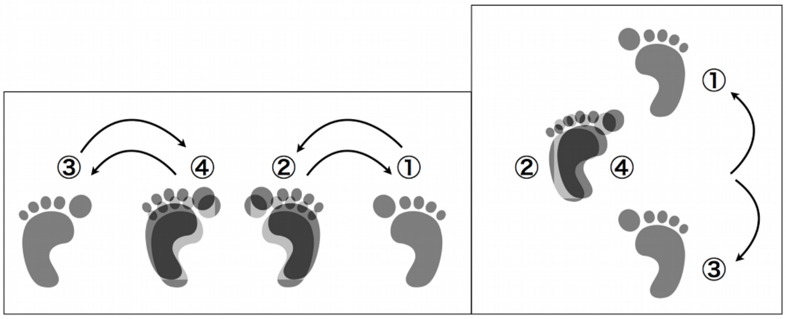


Figure 8.3. Example of didactic exercises to develop a sense of pulse in a 4/4 measure: the direction of stepping differentiates weak and strong beats: leaving a central position for the strong beats (1 and 3), going back to the central position for the weak beats (2 and 4).

8.4.2 The musical instrument as an embodied mediation technology

Apart from its grounding in teaching experience, the work on the Music Paint Machine has been inspired by the theory of embodied music cognition (Leman, 2007), including a viewpoint on the relationship between musician and musical instrument (Nijs et al., 2009). According to this paradigm, the body is a key component of musical meaning formation processes. What happens in the mind depends on properties of the body and therefore body and body movement have an impact on meaning formation. That way, the body acts as a mediator between experience and physical reality, allowing an engagement with music as some form of behavioural resonance. Given this viewpoint on the human body as a natural mediator, musical instruments can be considered as artificial extensions of the body. These instruments allow the mind to operate within a reality (namely the musical reality) that is otherwise not accessible. Therefore they can be considered as mediation technologies. But musical instruments not only open up new worlds, they also influence the way the body mediates experiences. Musical instruments require certain movements (sound generating gestures) and thereby possibly restrict the body in its freedom to move and freely resonate with the music. By doing this, they have a major impact on musical meaning formation. Therefore it is necessary to establish a relationship with the musical instrument that makes an embodied interaction with the music possible. The paradigm of embodied music cognition also highlights the multimodal nature of musical experience, which suggests that educational feedback in multiple modalities intensifies musical experience and learning processes (e.g. Ng, Larkin, Koerselman, & Ong, 2007; Yu, Lai, Tsai, & Chang, 2010).

Given this theoretical framework, the Music Paint Machine can be seen as an extension of the musical instrument and therefore, as a mediator that is fully connected to the player's bodily engagement with music. For example, it integrates visual feedback on body movements and stimulates music students to explore the possibilities of their instrument and experiment with movement and musical parameters. By completing drawing tasks, movements can be used to elicit an embodied understanding of certain musical elements such as phrasing, dynamics and articulation (transition between notes or not). Because the Music Paint Machine offers the possibility to represent movement and sound in a common visual stimulus, it accommodates the multimodal nature of musical expression and involvement.

8.4.3 Flow, presence and a constructivist approach to assessment

Finally, as mentioned in Section 1, the concept of the Music Paint Machine is also based on the literature on flow experience (Csikszentmihalyi, 1990; Custodero, 2005) and on a constructivist approach to education (e.g. Pritchard & Woollard, 2010). This also led to a theoretical investigation of the assessment of flow within the context of the part-time music educational system, and the development of a model for a possible evaluation approach to music education (Nijs, 2008). This background in psychology and education was important for embedding the concept of the Music Paint Machine in a pedagogical framework and, together with the emerging views on assessment, for tailoring the design of the application to different didactic uses, such as experimentation (e.g. Olsson, 2009) and paintings as pedagogical documentation (Dahlberg, Moss, & Pence, 1999; Buldu, 2010).

Flow is defined as an optimal experience that occurs when a person experiences a balance between the perceived challenges of a situation and his or her skills or capabilities for action (Csikszentmihalyi, 1990). It implies that the subject is completely and from moment-to-moment involved in the ongoing activity to the point of forgetting everything else except for the activity itself (time, personal concerns, instrument). Attention is given to the task at hand, and the person functions at his or her fullest capacity. Flow experience has been used in quite a number of studies on music education, with or without the use of interactive music systems (e.g. Custodero, 2002; Addessi et al., 2006). The presented research fits within this growing field of flow-related educational research.

To further elaborate on the concept of flow (see also: Riva, Waterworth, Waterworth, & Mantovani, 2009) and to refine the knowledge on how musicians interact with both acoustical instruments and technology-enhanced learning tools such as the Music Paint Machine, we also use the concept of presence. Presence can be defined as an internal psychological feedback system that does not involve conscious awareness and relates to a moment-by-moment self-monitoring of the behaviour (Welch, Howard, Himonides, & Brereton, 2005). In other words, presence informs a person whether actions are performed in accordance with his/her intentions and goals (Riva, 2008b; Riva et al., 2009). Up to now, the concept of presence has been mainly used in the domain of human–computer interaction (HCI) and virtual reality, where it is defined as 'the feeling of being and acting in a world outside ourselves' or 'the feeling of being and acting "there"' (e.g. Schubert, Friedmann, & Regenbrecht, 1999). When bodily sensations, perception and cognition coherently collaborate to keep attention focused on this outer world ('there'), a maximal sense of presence is experienced.

We are not aware of any studies in which the concept of presence is used in the domain of music education and performance or in which a presence questionnaire is applied to probe subjective experience when using an interactive music system. However, we do believe that the concept of presence is useful to investigate the musician-instrument relation within the context of technology-enhanced learning, especially in the context of tool development that addresses the enhancement of self-monitoring. We believe that an elaboration on this concept within the field of music research can significantly contribute to revealing the basic components of an embodied interaction during music performance (Leman, 2007; Nijs et al., 2009).

The conceptual framework that underlies the Music Paint Machine fully subscribes a constructivist approach to education. This approach emphasizes (i) the autonomy and self-regulation of the students in the process of learning, and (ii), the creation of powerful learning environments in which this autonomy can grow and the knowledge, skills, and attitudes associated with self-regulation can be acquired. It is exactly in this creation of the learning environment that the flow theory, in combination with the theory of embodied music cognition, corresponds with constructivism. Flow theory links to the constructivist idea of the learners' autonomy by attributing an important role to the personal experience and the way learners shape this experience through different behavioural strategies (Custodero, 2005). The theory of embodied music cognition adopts a specific viewpoint on the role of the human body and the technological tools used for interaction. These theories are linked with the idea that an optimal learning environment is created through an activity that is perceived as meaningful and challenging within reach of one's skills. Perceiving this balance between challenge and skills is achieved through the process of self-monitoring.

The Music Paint Machine is assumed to contribute to the establishment of such a powerful learning environment by providing students with a 'phenomenarium' (Perkins, 1992) that introduces learning as an active process in which meaning is constructed on the basis of experience. Thereby, it contributes to a learner-centred approach and promotes exploration and experimentation, both important aspects of a constructivist approach to education. It engages the learner in an interactive loop between playing and visual output in which the visual output gives immediate and intrinsic feedback on movement and sound. Through this interactive process, it helps students to construct their own knowledge. It also provides students and teachers with an elaborated off-line feedback on their playing by showing different visualizations of the painting and data on movement (e.g. amount of movement) and sound (pitch, dynamics) by means of the integrated log system. Both the creative output of the Music Paint Machine and the off-line objective feedback, can function as important pedagogical documentation that makes the combination of product evaluation on the one hand and participatory and formative evaluation on the other hand possible (Dahlberg et al., 1999; MacDonald, 2007). Furthermore the paintings can be used for student portfolios and peer evaluation (e.g. Goolsby, 1995; Daniel, 2004).

8.5. Hard- and software: implementing the concept in a first prototype

8.5.1 Overview of the system

The Music Paint Machine allows a musician to make a painting on a computer screen by playing music and moving on a coloured mat (see Figure 8.4). Sound and movement are tracked, analyzed and transformed into a visual output. The musician engages in an interactive loop between playing music and moving on the one hand and the visual output on the other hand. The system as presented in this section, is the result of the iterative process as described in Section 2.

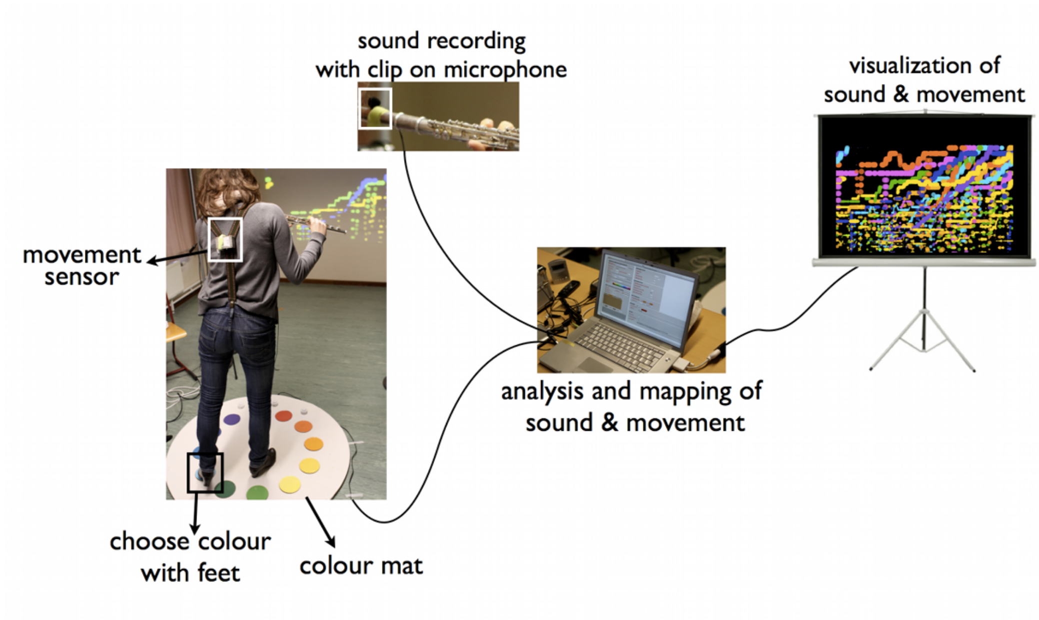


Figure 8.4. Overview of the Music Paint Machine. The system provides a game-like environment in which a musician can create a digital painting (right) by playing an acoustic musical instrument and moving the body on a coloured pressure mat. Sound and movement are measured, analyzed, mapped and visualized on the screen.

8.5.2 System design

8.5.2.1 Motion sensor

The user's movements are tracked using inertial measurement sensors.[5] The motion tracker incorporates four sensors: an LY530AL (single-axis gyro), LPR530AL (dual-axis gyro), ADXL345 (triple-axis accelerometer), and HMC5843 (triple-axis magnetometer), resulting in nine degrees of inertial measurement. Individual sensor output is processed by an on-board ATmega328 using a Direction Cosine Matrix (DCM) to obtain the orientation of the motion tracker. The resulting orientation vector is then sent to the computer using a wireless Bluetooth connection. The motion tracker is powered by a 800 mAh Li ion battery, capable of providing power to the device for several hours. Everything is built into a small enclosure, measuring 7.5 cm 6 5 cm 6 2.5 cm, which can be attached to the back of the subject without restricting movement.

[5] Sparkfun Razor 9DOF IMU AHRS: http://www.sparkfun. com/products/9623

8.5.2.2 Coloured mat

The coloured mat consists of 16 pressure points that can be activated by stepping onto them. Twelve round pressure points represent the twelve different colours that can be chosen while playing. Their size equals the size of a CD (1 12 cm) and they are organized in a circular configuration (1 70 cm). Each of these pressure points consists of three monostable micro switches that are wired in parallel and establish a connection between a mass and its respective digital input on an arduino board. The latter is programmed to send changes in its state (the last button pressed) over the serial link to the computer. Four other monostable micro switches are positioned outside the circle of colours and serve additional functions (start, stop, erase, save). They are connected to the analogue input on the arduino board. Micro switches, wires and arduino board are embedded in a round MDF panel (1 115 cm).

8.5.2.3 Software

The software for the recognition and processing of sound and movement is programmed in MaxMSP, a graphical programming environment for real-time audio processing (M. Puckette & D. Zicarelli. Max/MSP. Cycling 74/ IRCAM, version 5.0, 1990–2010). Pitch and amplitude of the sound are tracked by the Sigmund-object (Puckette, Apel, & Zicarelli, 1998).

The visualizations are programmed in Processing, an open source programming language and environment used to create images, animations, and interactions.[6] The painting consists of a black canvas, projected onto the entire screen, and a round brush used to move inside this canvas. The brush has several parameters: position, radius, colour and transparency. These parameters are sent from Max/Msp to Processing using the OSC protocol.

8.5.3 Mapping

An important aspect of the Music Paint Machine is related to the idea that the unity of body and the acoustic musical instrument becomes the controller, i.e. a device to control what happens on the screen. The visual display is the result of playing the instrument and at the same time moving the body in a way that is not limited to sound producing gestures. Accordingly, sound and movements are mapped to the visual domain (see Figure 8.5). Because producing the music is a

[6] Processing 1.0, retrieved September 7, 2012 from www.processing. org

question of playing the musical instrument, movement is not directly mapped to sound. However, by requiring additional movements to use the Music Paint Machine, the sound generation might be influenced (as it is in 'normal' playing) by the musician's movement and this can change the visual output. Thereby, it can affect the interactive loop between music, movement and painting.

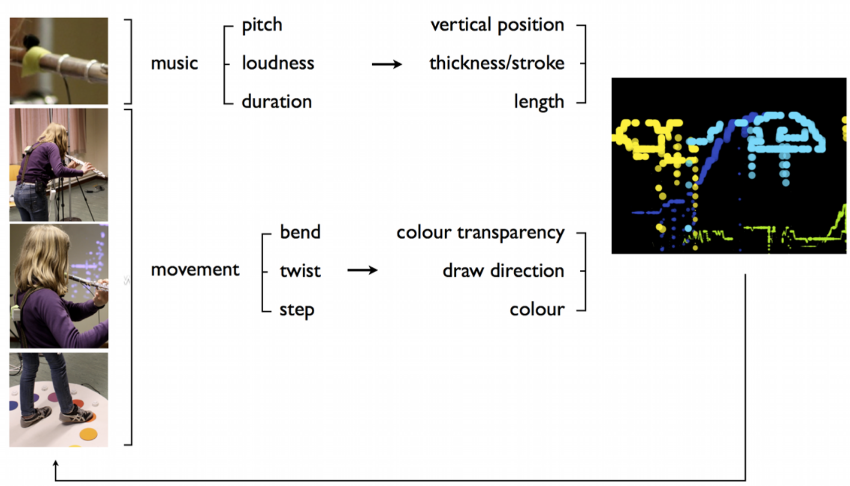


Figure 8.5. Overview of the mapping of movement and sound to the visualization. Movements of the feet and torso control colour, colour transparency and drawing direction. Sound parameters are mapped to vertical direction and stroke thickness.

8.5.3.1 Mapping body movement

Two kinds of movement are central to the mapping of the Music Paint Machine: the movement of the torso and the movement of the feet. Movements of the torso are tracked with the motion tracker. After calibration, two parameters are extracted: the left–right orientation of the user's torso and the amount of bending forward. Lateral movement (roll) of the torso determines the position of the paintbrush on the horizontal axis. When the torso is oriented to the right, painting goes from left to right and vice versa when the torso is oriented towards the left. Vertical movement of the torso (pitch) influences the opacity of the currently activated colour by increasing transparency when bending forward.

To activate colours, users move their feet on the coloured mat and step on the coloured pressure points. Numbers are sent to MaxMsp and associated in Processing with the colour of the pressure point.

8.5.3.2 Mapping musical features

Apart from the colour, the drawing direction and the transparency, all other drawing commands are determined by musical features. To block out the surrounding noise, wireless clip-on microphones are placed on the instrument. When no sound is produced, nothing is drawn on the screen. Consequently, a sustained note produces a horizontal line, while a very short note (e.g. staccato playing style) produces a dot. The vertical position of the paintbrush on the canvas is determined by pitch (notes). Therefore a melody produces a curved line. The stroke size of the paintbrush is determined by the loudness of what is played. The louder a user plays, the bigger the stroke size becomes.

8.5.4 Play modes

We foresee two ways to use the Music Paint Machine. A first play modus allows musicians to freely explore the combination of moving, playing and drawing. This is the play mode that has been used in the experiments discussed in this paper. We foresee a second play mode in which methodically designed learning paths (e.g. articulation, melodic contour, tone production) are implemented.

8.6. Experimental setup

An experimental protocol was established to investigate the Music Paint Machine's potential to induce an optimal experience in the musician and to learn about the way musicians (both teachers and amateur musicians) evaluate the didactic potential of this application. In this paper, we report on experiments with amateur musicians as participants.

8.6.1 Participants

Fifty-one amateur musicians participated in the experiment. They were recruited through social network sites and through contacts with different music schools. Furthermore, websites were created to inform possible participants on the experiment and to organize the sessions. All participants were informed about the procedure and participated on a voluntary basis.

Over two-thirds (68.63%) of the participants were female. Their average age was 21 years and 78.4% of them were under the age of 25. Participants' main instruments are flute (31%), saxophone (24%), clarinet (16%), violin (12%) and a mixture of other wind instruments (17%). They have been playing their instrument for 1–7 years (53%) or longer (47%). The majority (78%) of them are currently following music lessons in the department of classical music within formal music education. Most participants play at least once a week at the music school (80.4%). Furthermore, participants reported that they mostly (35%) or even always (47%) play music from a score. Over half of the participants stated that they never (18%) or rarely (35%) improvise. Most of the participants use the computer daily (56%) or every two days (33.3%). Computer applications for music are rarely used.

8.6.2 Materials and setting

The material that was used for the experiment comprised the Music Paint Machine and its components (i.e. coloured mat, computer, motion sensor, clip on microphones). The computer screen was projected onto the classroom wall or screen using a beamer. Two digital video cameras were used: one videotaped the musician, the other the screen.

Experiments were mostly conducted in music schools, involving 73% of the participants. Amateur musicians, who no longer followed instrument lessons and therefore were not able to attend the sessions in schools, tested the Music Paint Machine at the research lab (27%). Apart from the different locations, material and setup used were identical.

8.6.3 Procedure

Prior to the experiment, a pilot study involving students (n = 9) and teachers (n = 6) was conducted to refine the methodology. Results from this study lead to the refinement of pre- and post-questionnaires. The timing for testing the application was set to 10 min of actual testing, based on observatory information gained during the pilot study and on inspection of the video recordings.

The actual experiment consisted of three sequential parts. During the first part, participants were first asked to fill in a background questionnaire. Participants were requested to answer general questions related to age and gender. They also had to specify to what extent they agreed with statements about their musical background and their computer use. A non-forced seven-point Likert scale was used to do this. A final set of questions probed participant's personality, based on the Dutch version of the Big Five Inventory (Denissen, Geenen, van Aken, Gosling, & Potter, 2008). These questionnaires were done prior to the actual testing during which participants performed with their musical instrument while interacting with the Music Paint Machine. Because this experiment involves the testing of a prototype technology-enhanced learning tool, we assumed that personality might play a role in the way the Music Paint Machine is experienced and in how its didactic potential is evaluated.

During the second part, the Music Paint Machine was tested. Firstly, participants were informed on how to use the system so that they could learn about the mapping of the system. This step included the calibration of the system according to the skills of the player, such as the adaptation of the screen resolution to the range of notes the participant could play or the adaptation of the brush size to the dynamical range of the participant's playing capabilities. Finally, the participant was allowed to test the system for 10 minutes. The task was formulated as follows: 'Please draw one or more paintings on the screen, by playing music with your instrument and by moving on the coloured mat'. It was clearly said that they could draw whatever they wanted, whether figurative or abstract and that the label of bad or good was not applicable to the paintings. Within the given 10 minutes, each participant could try out the tool and 'draw' one or more paintings by playing their instrument, depending on their personal way of completing the task. This part of the experiment was videotaped.

During the third part of the experiment, participants were asked to fill in a post-questionnaire with three sets of questions. The first two sets of questions aimed at measuring the quality of their subjective experience (dependent variable) while playing music and interacting with the Music Paint Machine (independent variable) to make a painting. The first set comprised the questions of the Flow State Scale (Jackson & Eklund, 2004). The second set of questions, the Presence State Scale, was designed on the basis of the presence factors as defined by Witmer and Singer (1998). Finally, a third set of questions was asked to learn more about the way participants evaluate the didactic potential of the Music Paint Machine (dependent variable) after having experienced playing with it (independent variable).

The Flow State Scale (Jackson & Eklund, 2004) probes the participants' experience with the system by means of 36 questions that can be grouped into nine dimensions of flow experience (Csikszentmihalyi, 1990). These nine dimensions can be grouped into conditions, characteristics and consequences (Chen, Wigand, & Nilan, 1999). The scores of these dimensions are combined to measure an overall scale that represents the flow state of the participant (see Table 8.1). The Flow State Scale questionnaire (Jackson & Eklund, 2004) was translated into Dutch. We used a seven-point Likert scale ranging from ‘completely disagree’ to ‘completely agree’. Both the consistency of the results (when comparing individual questions and dimensions) and a Cronbach’s alpha test ($\alpha = 0.921$) confirmed the reliability of the questionnaire.

Table 8.1. Design of the questionnaire about flow experience: 36 questions (variables) are grouped into nine dimensions, which can be subdivided into three categories. The Flow State Scale (FSS) is an overall measure of the quality of the user experience, based on the mean of the dimension scores.

Flow			
FSS	Categories	Dimensions	
	Conditions	1. challenge/skill balance	*personal skills are well suited to the given challenges*
		2. clear goals	*objectives are clearly defined*
		3. unambiguous and immediate feedback	*one knows instantly how well one is doing*
	Characteristics	4. merging of action and awareness	*one-pointedness of the mind*
		5. concentration on the task at hand	*irrelevant stimuli disappear from consciousness, worries and concerns are temporarily suspended.*
		6. sense of control	*the ability to take control of the situation without any conscious effort*
	Consequences	7. altered time perception	*time passes differently from normal*
		8. loss of self-consciousness	*the concern for oneself disappears while engaging in the activity*
		9. autotelic experience	*enjoying the activity for its own sake*

The Presence State Scale probes the participants’ experience with the system by means of 20 questions that were based on the presence factors as defined by Witmer and Singer (1998) (see Table 8.2) and elaborated on control, distraction, sensory experience and realism of the system. We used a non-forced seven-point Likert scale from ‘completely disagree’ to ‘completely agree’. Cronbach’s alpha for this questionnaire was 0.610. Therefore it is important to further refine the presence questionnaire for future experiments and to optimize its internal consistency. Following the Flow State Scale procedures, we calculated an overall score for Presence, the Presence State Scale (PrSS).

A third series of questions was devoted to the didactic possibilities of the Music Paint Machine. Questions focused on improvisation, creativity, listening skills and feedback. We are aware of the fact that the actual didactic potential of the system does not necessarily coincide with the perception and opinions that teachers and students might have about the didactic potential of the system after having experienced the prototype once. However, we acknowledge and value the students' and teachers' practical knowledge as a basis for an evaluation of the system. Additionally, some students (n = 8) participated in an exploratory focus group and were asked to discuss the didactic potential of the Music Paint Machine.

Table 8.2. Design of the questionnaire about presence: 20 questions (variables) are grouped into four presence factors as defined by Witmer and Singer (1998). The Presence State Scale (PrSS) is an overall measure of the quality of the interaction, based on the mean of the presence factors.

Presence		
PrSS	PRESENCE FACTORS	
	Control Factors	Immediacy of control
		Anticipation of events
		Mode of control
		Physical environment modifiability
	Sensory Factors	Sensory modality
		Environmental richness
		Multimodal presentation
		Consistency of multimodal information
		Degree of movement perception
		Active search
	Distraction Factors	Isolation
		Selective attention
		Interface awareness
	Realism Factors	Scene realism
		Information consistent with objective world
		Meaningfulness of experience
		Separation anxiety/disorientation

8.6.4 Data analysis

Statistical analysis of all questionnaire data was performed using PASW 18.0. The aim of the analysis was to gather knowledge (1) on the users' experience while being engaged in the interactive loop between playing music, moving and drawing when using the Music Paint Machine in its explorative modus (no specific drawing or musical tasks) and (2) on their evaluation of this application's didactic potential. The data analysis process involved descriptive statistics (e.g. background, didactic potential), correlation and regression analysis of flow and presence and variables. Analysis was performed on the level of individual variables (e.g. enjoyment, focus of attention), groups of variables (e.g. flow dimensions, presence factors) and total scores (e.g. Flow State Scale, Presence State Scale). The non-parametric Spearman's rank correlation test was used to cope with deviations from normality. Furthermore linear regression was used to compare groups of variables with calculated total scores.

8.7. Results

8.7.1 Flow experience

The scores of the Flow State Scales varied from 3.63 to 6.59 on a seven-point Likert response format from strongly disagree to strongly agree (See Table 8.3). The moderately high overall mean (5.07, *SD* = 0.7) indicates that the Music Paint Machine is likely to have the potential to turn the experience of playing music, moving and drawing, into an optimal or flow experience. A statistical analysis of flow experience aimed at finding the components that need to be considered when developing this application.

Table 8.3. Means and standard deviations of the scores for flow dimensions, categories and scale. Results indicate the application's potential to elicit a fun experience in which musicians can interact with the system at every skill level.

Scale	*M*	*SD*
1. Challenge/skill balance	**5.19**	.86
2. Clear goals	4.12	1.12
3. Unambiguous and immediate feedback	4.44	.95
4. Merging of action and awareness	4.18	1.47
5. Concentration on the task at hand	**6.05**	.90
6. Sense of control	4.75	1.28
7. Altered time perception	5.09	1.26
8. Loss of self-consciousness	**5.77**	1.00
9. Autotelic experience	**6.03**	.75
Conditions	4.58	.83
Characteristics	4.99	.95
Consequences	5.63	.70
Flow State Scale	5.07	.70

Firstly, scores for individual flow variables were compared, using the non-parametric Spearman's rank correlation test to look for significant associations. To select the most important associations between variables, rank correlations were considered to be significant when $p < .05$. They were considered to be strong when $r_s = .600$ and moderate when $r_s = .400$.

Secondly, a descriptive analysis was done on the level of dimensions. Table 3 clearly shows that the dimensions 1 (balance between skills and challenge), 5 (focused attention), 7 (loss of self-consciousness) and 9 (autotelic experience) have the highest scores. These results indicate the Music Paint Machine has the potential to elicit a fun experience in which musicians can play with the system at every skill level. This means this application can be used for all grades, from beginner to advanced student. Apparently using this application makes attention very focused, even to the degree that one loses self-consciousness.

However, one of the core aspects of the Music Paint Machine, namely providing clear and immediate feedback, receives a lower score (M = 4.44, SD = .95). The dimension of 'clear goals' had the lowest score (M = 4.12, SD = 1.12). This is possibly the result of the explorative character of the experiment. They could play, move or draw in whatever way they wanted. Although participants could set their own goals (e.g. 'I will draw my name'), receiving no specific tasks may have contributed to the fact that participants scored still positive but lower for this dimension. In order to see how the possible lack of clear goals affected the other flow dimensions, we first performed a Shapiro–Wilk normality test. Only the dimensions of 'loss of self-consciousness' and 'concentration on the task at hand ' were not normally distributed. To determine the relationship between the normally distributed dimensions, Pearson correlation tests were performed and showed different significant relationships between flow dimensions. Significant positive relationships were found between 'clear goals' and 'Unambiguous and immediate feedback' (r = .734, p < .001), 'sense of control' (r = .555, p < .001) and 'merging of action and awareness' (r = .541, p < .001). This means that the lack of clear goals has an effect on the way feedback is experienced and to what degree one feels in control of the system. Furthermore, 'merging of action and awareness' was significantly positively correlated to 'Unambiguous and immediate feedback' (r = .612, p < .001) and to 'sense of control' (r = .788, p < .001). Because 'merging of action and awareness' is the flow variable with the second most strong positive correlation with the Flow State Scale (r = .799, p < .001) and because of the strong correlation between clear goals, unambiguous feedback and sense of control, further use of the Music Paint Machine needs to take into consideration the setting of clear goals.

To see how both non-normally distributed dimensions affected the other dimensions, Spearman's rho test was used. Results did not show significant correlations with the other dimension, only a moderate but significant positive association between 'concentration on the task at hand ' and 'loss of self-consciousness' (r_s = .410, p = .003).

The findings described above not only confirmed the internal consistency of the Flow State Scale questionnaires, they also reveal the variables (e.g. 'clear goals') that can be influenced and therefore used as dependent variables in forthcoming experiments.

Thirdly, the categories of flow conditions, characteristics and consequences were measured in the same way as the Flow State Scale, that is, by calculating the average of the dimensions that belong to each category. The Shapiro–Wilk test for normality was then used to provide us with evidence to use a simple linear regression analysis. It was found that flow conditions (independent variable) significantly predicted flow characteristics (dependent variable) scores (b = .793, $t(49)$ = 6.731, p < .001). Flow conditions also explained a significant proportion of variance in flow characteristics scores (R^2 = .48, $F(1,49)$ = 45.3, p <.001). Furthermore, flow characteristics (independent variable) predicted flow consequences (dependent variable) scores (b = .322, $t(34)$ = 2.740, p <.001). Flow characteristics also explained a significant proportion of variance in flow consequences scores (R^2 = .18, $F(1,34)$ = 7.51, p < .001). These results empirically confirm the categorization of flow variables into the three dimensions of conditions (when flow can occur), characteristics (what happens when it occurs) and consequences (effects of flow).

Because it was assumed that the participants' background might influence their subjective experience, we carried out a Spearman's correlation test in order to look for possible correlations between background and flow variables. Results showed moderate negative correlations. However, considering the non-normal distribution of participants' age, the same procedure was applied to all participants under the age of 25. The results for all participants were confirmed and additionally some correlations became stronger and more significant. In Table 8.4, we present an overview of these results.

Table 8.4. Spearman's correlation coefficients for the relationship between age and flow dimensions and scale. Results suggest that the fun factor of the application is age-related: the younger participants were, the more likely they had a fun experience.

Flow	Age	
	all participants	*> 25*
Clear goals	**r_s = -.229, p = .106**	**r_s = -.352, p = .026**
Unambiguous and immediate feedback	r_s =-.294, p = .036	r_s =-.324, p = .042
Merging of action and awareness	r_s =-.431, p = .002	r_s =-.437, p = .005
Sense of control	r_s =-.441, p = .001	r_s =-.473, p = .002
Altered time perception	**r_s = -.276, p = .050**	**r_s = -.115, p = .478**
Autotelic experience	**r_s = -292., p = .038**	**r_s = -.462, p = .003**
Conditions	r_s =-.288, p = .040	r_s =-.361, p = .022
Characteristics	r_s =-.455, p = .001	r_s =-.436, p = .005
Flow State Scale	**r_s = -.386, p = .005**	**r_s = -.371, p = .019**

The same procedure was followed to detect possible correlations between musical background (which instrument the participant played, for how many years, in what kind of situation they mostly play or whether they use scores or rather play by heart or improvise) and flow variables. Results show no clear correlations between the instrument that was played and flow experience. This means that the Music Paint Machine can be used with many different musical instruments. Moderate but significant negative correlations were found between the fact that a participant was still following lessons and the dimensions of 'challenge/skill balance' (r_s = -.278, p = .048) and 'merging of action and awareness' (r_s = -.301, p = .032). Participants who were still following lessons tended to score higher for these dimensions. We followed the same procedure for participants under the age of 25. Most importantly, the correlation between the fact that a participant was still following lessons was stronger and more significant for two flow dimensions, namely 'challenge/skill balance' (under 25: r_s = -.422, p = .007; all participants: r_s = -.278, p = .048) and 'sense of control' (under 25: r_s = -.413, p = .008; all participants: r_s = -.244, p = .084). Even if a large majority of the participants rarely or never improvise or play by heart, previous experience with both was not significantly correlated to the different flow variables.

8.7.2 Presence factors

For the analysis of the presence questionnaire data, the following steps were undertaken: (1) a descriptive analysis and Spearman's rank correlation test for the scores of individual questions, (2) the Pearson correlation test to assess the relationship between the different presence factors, (3) the Spearman's rank correlation test to test for correlations between background variables and presence variables, and (4) the Pearson correlation and Spearman's rank correlation tests and simple linear regression analysis to find associations between flow and presence variables.

First, an analysis of the individual variables was done. A descriptive analysis showed that, although three quarters of all participants (76.5%) felt the need to get used to the application before they could really manage it, 43.1% of all participants nevertheless disagreed that the Music Paint Machine requires a long learning process before being able to use it spontaneously. By far the most participants (92%) stated that they succeeded in drawing something on the screen in different ways and 72.5% even felt they could do what they wanted. It was encouraging to see that three quarters of the participants (76.5%) experienced the mapping of movement and sound to the visual output as natural. Nevertheless, only 43.1% of participants found that the actions necessary to draw do not deviate too much from the way they normally play their instrument and 41.2% stated that using the Music Paint Machine requires a mental effort. This can be explained by the fact that there was no learning phase included in the experiment. Finally, 90.2% reported that the Music Paint Machine stimulated them to be more creative with musical parameters.

To assess the relationship between the different presence variables, Spearman's rank correlation coefficients were calculated. The strongest positive correlations were found between the need to get used to the system and the feeling that 'a long learning phase is necessary' (r_s = .549, p < .001), between 'it felt natural to use the system' and 'the system responded well to one's actions' (r_s = .491, p < .001), between 'the ability to predict the effect of one's actions' and the experience that 'the coupling between actions and effects felt natural' (r_s = .563, p < .001), between whether 'it felt natural to use the system' and the fact that 'mediating technologies did not distract attention from the task at hand' (r_s = .607, p < .001) and the experience that 'the coupling between actions and effects felt natural' (r_s = .536, p < .001) and finally between the feeling that 'a long learning phase is necessary' and the feeling that 'using the system requires a mental effort' (r_s = .626, p < .001). Strong negative correlations were found between the feeling that 'the system responded well to one's actions' and the feeling that 'a long learning phase is necessary' (r_s = -.541, p < .001) and the feeling that 'using the system requires a mental effort' (r_s = -.597, p < .001). These results suggest that (1) the immediacy of the visual feedback strongly influences the way the system is experienced, (2) it is important that the used technologies do not require too much attention and (3) the mapping makes sense.

Secondly, we performed an analysis of the presence factors and the presence state scale. To calculate the presence state scale, scores for questions on learning phase, abnormality of task-related aspects and attention were reversed. Next, the averages of the scores related to the different factors were calculated to determine the scores of the presence factors. The presence state scale was calculated by averaging the presence factor scores, following the same procedure as the calculation of the flow state scale score.

In Table 8.5, the mean and standard deviation for the different presence factors and the overall presence score or presence state scale are presented. The factor with the highest score (M = 5.13, SD = .82) is the realism factor. This factor is related to the way in which participants experienced the system with regard to the mapping of movements and sound to visual effects. It also refers to the degree to which users experience the system as stimulating creativity with musical parameters. These results indicate that no important changes in the current mapping are necessary.

Table 8.5. Mean and standard deviations of the scores for presence factors. The high score for the realism factors suggest that the Music Paint Machine provides a meaningful experience.

Scale	*M*	*SD*
Control factors	4.51	0.99
Sensory factors	4.56	0.63
Distraction factors	4.64	0.81
Realism factors	**5.13**	**0.82**
Presence State Scale	4.69	0.45

The Shapiro–Wilk test for normality enabled us to make use of the Pearson correlation test to assess the relationship between the different presence factors. Results show a strong positive correlation between control factors and realism factors (r = .578, p < .001) and a moderate correlation between sensory factors and distraction factors (r = .364, p = .012). It is interesting to learn that the presence state scale shows a significantly strong correlation with the control factors (r = .833, p < .001) and the realism factors (r = .686, p < .001). This means that mapping (realism factor) and the ability to exert a fine-grained control over the different parameters (control factor) are determinant aspects of engaging with the Music Paint Machine.

Thirdly, we assessed relationships between presence and background because, as is the case with flow experience, we assumed that background variables might influence the subjective experience of the participants. Regarding the total number of participants (N = 51), Spearman's correlation test showed significant negative correlations between the control factor and age (r_s = -.388, p = .005) and between the control factor and whether a participant was currently following lessons (r_s = -.319, p = .022). Perhaps counter intuitively but in line with the Music Paint Machine's goal to make the application suitable to all skill levels, the control factors were not positively correlated with the number of years that participants had been playing their instrument but results showed a weak but nevertheless significant correlation (r_s = -.290, p = .005). We are of course aware that the number of years does not necessarily say something about the skill level. On the other hand, we found a positive correlation between the sensory factor and number of years playing the instrument *(r_s = -.481, p = .001).* Because of the non-normal distribution of age and participants following lessons or not, we applied Spearman's correlation test to the scores of participants that were under 25 and still following lessons. Correlations were confirmed, became slightly stronger but the significance of the probability was lower. It is worthwhile to mention the fact that within this subset an additional moderate but statistically significant correlation was found between the amount of time participants played from the score and the presence control factor (r_s = .449, p =

.006). This is rather remarkable because, apparently, people who are not used to improvising, felt nevertheless in control over the system regardless of the fact that they were actually improvising. Again this corresponds to one of the aims of the Music Paint Machine, that is, introducing painting as a familiar activity to lower the threshold for an activity one is not familiar with, namely improvising. In order to determine correlations between background and presence, the experiment has to be repeated with participants that are older than 25, that do not follow lessons anymore and that are familiar with improvisation and with playing by heart.

Fourthly, relationships between flow and presence variables were investigated. Regarding individual variables, we found many significant associations between flow and presence questions by using the Spearman's rank correlation test, which indicates a close relationship between both kinds of subjective experience. The presence variables that often correlated (positively or negatively) with individual flow variables were 'mediating technologies did not distract attention from the task at hand' (non-mediation), 'the coupling between actions and effects felt natural' (natural mapping) and 'using the system requires a mental effort' (cognitive load). To assess the relationship between flow and presence variables at higher levels, we compared individual presence variables to flow dimensions and to the Flow State Scale. Spearman's rank correlation coefficients were calculated and showed many significantly moderate to strong correlations, confirming the relationship between flow and presence as qualities of participants' subject experiences (see Table 8.6).

Table 8.6. Spearman's correlation coefficients for the relationship between individual presence variables and flow dimensions, categories and scale. Results empirically validate the theoretically elaborated relationship between the concepts of flow and presence.

Presence Variables	Flow Dimensions									Categories			FSS
	1	2	3	**4**	5	**6**	7	8	9	Cond	Char	Cons	
feeling of being able to do what one wants to do				.357		.453				.369	.443		.489
the system responded well to one's actions			.358	.522		.571			.356		.535		.499
perceived ability to predict effect of actions		.367		.524		.523					.524		.436
it felt natural to use the system	.426	.647	.724	.669		.640			.372	.724	.689		.725
feeling successful in drawing in different ways		.390					.402					.482	
attention directed to screen					.483								
attention directed to musical instrument						.394					.424		.394
mediating technologies did not distract attention from the task at hand	.396	.410	.458	.639		.578			.402	.514	.621		.636
the mapping of the system felt natural		.366	.491	.571		.470				.434	.511		.473
using the system requires mental effort				-.569		-.383					-.463		-.412

The results of comparing individual variables with each other and with the flow dimensions (means of individual variables) were mirrored in significant correlations between flow dimensions and two presence factors, namely the control and realism factors. This means that the concept of presence, i.e. an unconscious action monitoring system that informs the agent whether actions are under control, can be used to elaborate on the control dimension of flow. The correlation between flow and the realism factor points at the importance of the way a tool is experienced to allow for flow to occur in a tool-mediated activity. Finally, Pearson's correlation test revealed a significant strong correlation between the Presence State Scale and the Flow State Scale (r = 0.506, p 5 0.001). To further assess the relationship between both scales, a simple linear regression was performed after the inspection of the corresponding scatter plot and a Shapiro–Wilk normality test. The Presence State Scale (independent variable) significantly predicted the Flow State Scale (dependent variable), (b = .815, $t(45) = 3.934$, $p < .001$). The Presence State Scale also explained a significant proportion of variance in the Flow State Scale, ($R^2 = .256$, $F(1,45) = 15.5$, $p < .001$). These results confirm the relationship between both variables and support the link between both concepts. However, further experiments are necessary to learn more about their exact relationship.

8.7.3 Didactic potential

To rate the practical relevance of the application, questions about the didactic potential of the Music Paint Machine were included in the questionnaire. From the answers to these questions, we learned that most participants (78.4%) agreed that the visual feedback (what happens on the screen) has an added value and that it gives useful feedback on what and in which way they play (78.4%). Slightly fewer participants (74.4%) say that the visual feedback can help them to pay more attention to musical parameters. A remarkably large group reported that it could help them to understand these parameters better (80.4%) and to use them more prominently (84.3%). A number of participants stated that the required movements (turning left–right, bending, step with feet) interfere with their playing technique (33.3%) and their musical expression (23.5%). Because the different instrument groups show different means for the scores of these variables, one might be tempted to conclude that the scores of these variables are instrument related. However, the samples are too small for some groups to make this conclusion. More than two thirds (70.6%) of all participants think that an application like the Music Paint Machine might help them to learn how to play a musical instrument. Interestingly, most participants who acknowledged the application's potential to stimulate learning how to play an instrument, also believed that the application stimulates one to discover the instrument's possibilities (97.2% or 88.2% of all participants), to experiment with these possibilities (91%), to discover music (86%), to experiment with musical parameters (91% or 80.4% of all participants), to experiment with body movements (86.1% or 84.3% of all participants) and to experiment with what happens on the screen, i.e. the visual feedback or output (94.4% or 94.1% of all participants).

Spearman's rank correlation test did not show significant correlations between flow variables and variables concerning didactic potential, except from the fact that 'autotelic experience' shows some weak-to-moderate but significant correlations with several variables on didactic potential. This might indicate that having fun with the Music Paint Machine influenced the way participants evaluated the didactic potential of the application.

When comparing presence variables with variables on didactic potential, Spearman's correlation coefficients indicated weak-to-moderate but significant correlations between individual variables and between presence factors and variables on didactic potential. A significant moderate negative correlation was found between the presence control factors and the participants' evaluation of the visual feedback as disturbing (r_s = -.419, p = .002) and the participant's evaluation of the movements as disturbing musical expression. This means that when visual feedback and movements were experienced as disturbing, participants experienced less control.

8.8. Discussion of the correlation study

8.8.1 The subjective experience

The results suggest that the Music Paint Machine has the potential to induce a particular experience that is relevant within an educational context and that can moreover be probed with questionnaires about flow and presence. This is an important finding for several reasons. First of all, it shows that the tool, and in particular the feedback provided by the tool, does not hinder the user to be fully involved with the music. The fact that flow and presence score high suggests that the tool is able to provide students with intrinsic (task-related) feedback that is embedded in the experience of playing music and making a painting (cf. merging of action and awareness). Furthermore, the tool provides an immediate and highly responsive feedback (cf. control factors) that seems to support engagement and motivation (cf. autotelic experience). Both the aforementioned elements and the Music Paint Machine's additional possibility to provide offline feedback are essential aspects of intrinsic feedback. This finding supports therefore our hypothesis that self-monitoring can be enhanced by technology and that it has the potential to become fully integrated within an education context.

Secondly, the results about flow experience suggest that the tool has a potential to cope with the user's personal skill level. This result is reflected in the fact that the number of years that participants played their instrument was not a determining factor for the occurrence of flow. A feedback system that would not be able to cope with different skill levels is likely to show more variance in flow experience among its users because the tool's feedback would somehow occur as an obstacle for music playing, hence flow would be expected to be low. Moreover, even if most participants had almost no experience in improvising, they were able to experience flow to a certain degree while the task involved an activity they were not familiar with, namely improvising. None of the participants used a score and few of them played melodies from memory. This would suggest that the tool has a potential to stimulate improvisation.

Thirdly, the results suggest that another aspect of flow, namely the importance of clear goals and immediate and unambiguous feedback, is highly appreciated. It is known from the literature that flow can occur when goals are clear every step of the way and when feedback is immediate and unambiguous (Addessi & Pachet, 2005). Considering the monitoring capacities of the application, this is a crucial quality that can be attributed to the straightforward nature of the mapping from audio and movement to visual feedback. This mapping can be further explored but these first results indicate that a natural feel of the feedback in relation to music is an important flow-generating factor of the present tool. Moreover, the results show a strong correlation between the two flow dimensions, namely 'clear goals' and 'unambiguous and immediate feedback'. This confirms the importance of working with clear musical tasks and clear mappings in order to see whether feedback is effective.

The above results support the idea that when experiencing flow, there is less psychic energy invested in conscious self-monitoring. In such a state, the self-monitoring of action is processed at a subpersonal level that still enables one to discriminate between self-determined and world-determined changes in input (Russell, 1997). Therefore, with a view to stimulating these intrinsic feedback mechanisms, it is important that the technology-enhanced learning tool allows unconscious self-monitoring so that one can keep on concentrating on the action while playing the musical instrument instead of being engaged in an additional monitoring of the action while playing.

The self-monitoring of action is captured in the notion of presence, which is a mechanism that unconsciously compares the intended outcomes of an action to its actual outcome. Results from our experiment suggest a strong correlation between the occurrence of flow and presence. Thereby they support the idea that combining the concepts of flow and presence offers a valuable framework for probing the subjective experience that makes effective learning possible. In particular when learning is supported by technology enhanced tools. Indeed, while flow rather pertains to attention and focus in relation to skills, presence is more related to the interaction with the tools (e.g. acoustic musical instrument, a technology-enhanced learning tool) that are involved in the activity. Probing presence therefore informs on the degree to which a tool allows focusing on the task at hand and thereby disappears from consciousness (illusion of non-mediation). It is exactly this aspect that fully complies with the concept of embodied music cognition and the idea that the technology-enhanced learning tools can be developed as genuine mediators, that is, tools that connect to and even become a natural extension the human body (Leman, 2007; Nijs et al., 2009). In that sense, the Music Paint Machine can be seen as an extension of the musical instrument that is itself an extension of the human body. Therefore we believe that the concept of presence can offer an interesting extension of the flow concept, in particular to elaborate the control dimension of flow with regard to the use of technology-enhanced learning tools. The close relationship between both qualities of a subjective experience implies that soft- and hardware adaptations that optimize the system in function of the presence factors, will also positively affect its flow potential. That way it contributes to the embedding of feedback in the performance experience. An important related finding is the correlation between the control factors and realism factors. It confirms the importance of finding a good mapping between music, sound and movement. In the case of the Music Paint Machine, results show that the mapping is experienced as natural. Moreover, even if using the Music Paint Machine requires movements that one does not normally do while playing most instruments, this is not experienced as being too disturbing.

With regard to the probing of the participants' subjective experience, it is important to point out that the sample data (e.g. age, following lessons, background in improvisation) have a non-normal distribution. In forthcoming experiments participants will be selected in order to obtain a more balanced sample structure. Another aspect that needs to be taken into account is the explorative nature of the participant's task for the experiment. In the present experiment, participants could draw whatever they wanted, and consequently, their goals were not always very clear. Some people actually asked the researcher (who was behind the computer) ‘What should I draw?’. Presumably, this has affected the interactive loop and their evaluation of the visual output as possible feedback. Therefore, in forthcoming experiments, we may consider more concrete tasks, such as draw a ‘wave’. Such specific tasks may enable us to verify to what extent certain drawing tasks influence musical understanding. It might be that the use of certain drawing tasks is effective in allowing the musician to better understand the playing technique in relation to different musical parameters.

To conclude: so far, the results show that the concepts of flow and presence can be used to probe the subjective experience with the Music Paint Machine in such a way that relevant information can be obtained about the conditions that would make an efficient learning process possible. However, we have not yet been able to prove that learning becomes more efficient with than without the Music Paint Machine. Nevertheless our first results suggest that the conditions for efficient learning to occur are present.

8.8.2 The didactic potential

In this experiment, we also probed how participants estimate the didactic potential of the Music Paint Machine. Obviously, one should make a clear distinction between the user’s estimated didactic potential, and the veridical didactic potential, as the user may not always be able to estimate the learning effect while learning. Therefore, these results should be considered as indicative and less reliable. However, despite this difficulty, we believe that with regard to the importance of embedding the development of a technology-enhanced music learning tool within a pedagogical context, it is of interest to know what musicians, whether they are professional or amateur, whether they are teacher or not, consider the possible value of this application in music instrument lessons to be. We also believe that feedback from future users is essential for the development of the tool as a relevant didactic tool. The veridical didactic potential of this learning tool can only be tested by measuring learning effects. At this stage of the research, the latter was not yet feasible, but we believe that this approach may already provide us with interesting information for further development.

In any case, the results show a high degree of agreement about the Music Paint Machine’s didactic potential. The main finding is that the Music Paint Machine stimulates exploration of and experimentation with body movements, music and visual output. This is an important finding in view of using the Music Paint Machine as a support for an constructivist approach to music teaching and learning. Furthermore, participants agreed mostly that this application could be helpful for learning to improvise. Because exploration, experimentation and improvisation are often neglected in traditional music instrument lessons (Van Regenmortel & Strobbe, 2010), the Music Paint Machine can play a complementary role by providing an engaging and motivating experience.

8.9. General discussion

The development of a technology-enhanced learning tool for music education requires combining engineering skills, pedagogical expertise, and musicological insights into the nature of instrumental use and subjective experiences that can set the ground for effective learning.

We believe that the Music Paint Machine project has initiated a proper way of thinking about how music education can be made more efficient with a technology-enhanced learning tool. Yet, we are not yet able to scientifically prove that learning how to play music is indeed more efficient with than without the Music Paint Machine. What we can show so far is that the Music Paint Machine does not seem to hinder the playing, and perhaps promotes the conditions for efficient learning to take place. With that result in mind, it is important to reflect on the central contribution of a technology- enhanced learning tool for music education, namely the role of self-monitoring in learning and technology-enhanced learning with the Music Paint Machine.

8.9.1 Exploration and experimentation to promote self-monitoring

In a constructivist approach to education, exploration and experimentation by the learner are essential components of the learning process. These processes provide a creative space in which basic skills can be developed autonomously. Research on expertise indeed indicates goal imaging, motor production and self-monitoring as basic skills for performance (Ericsson & Lehmann, 1996; Lehmann, 1997). In contrast to the constructivist emphasis on exploration and experimentation, traditional music education considers self-monitoring and goal setting from a teacher-controlled viewpoint. Students are then supposed to develop the necessary self-monitoring skills (e.g. awareness, self-evaluation) based on the repeated feedback on different aspects of their playing as provided by the teacher. As a result, monitoring is tailored to the teacher's model, and learning is methodologically and hierarchically structured according to fixed learning paths that determine problems and their solutions in advance and leave little space for creativity (Olsson, 2009).

We acknowledge the importance of methodologically organized learning paths in music instrument education, and we believe that exploration and experimentation are necessary for a learner-centred approach to teaching. Both enable a shift from controlling music, which is largely based on teacher-controlled feedback (extrinsic) to experiencing music, which is based on feedback that is directly sensed from the act of performing (intrinsic). Accordingly, autonomous self-monitoring and self-regulation are promoted.

However, in contrast to the common presumption that self-monitoring is a conscious process, literature on the experience of flow and presence show that self-monitoring can be active without awareness (e.g. Csikszentmihalyi, 1990; Riva, 2005). Experiencing flow involves a feeling of being in control without having to consciously monitor ongoing actions. The mechanism that is responsible for this feeling is presence, defined as a sophisticated but unconscious form of monitoring of action and experience (Riva, 2008a). It is a control mechanism that tracks variations in subjective experience (breakdown or optimal experience). When no variations are sensed, all attention can be devoted to task related feedback and it becomes possible to be completely absorbed in the task. When this is the case, feedback is embedded in the performance and becomes intrinsic. Therefore, it is important to create powerful learning environments in which a carefully designed learning path integrates exploration and experimentation and provides students with engaging experiences. The goal of the technology-enhanced learning tool is thus to intervene in these processes in such a way that self-monitoring is enhanced.

8.9.2 New technologies and the role of real-time visual feedback

The development of new sensor technologies has led to the design of tools that aim at enhancing learning by real-time visualizations of different aspects of the performance. For example, a wide range of applications uses visual feedback to develop singing skills (e.g. Hoppe et al., 2006; Howard et al., 2004). Other applications aim at extending the music score with annotations that give feedback, for example, on accuracy and intonation (e.g. Kun, 2004; Fober, Letz, & Orlarey, 2007; Johnson & Han, 2009). Visual feedback is also used in learning tools that address music conducting (e.g. Borchers, 1997), learning to improvise (e.g. Franc ¸ois, Chew, & Thurmond, 2007), and developing musical expressiveness (e.g. Dixon, Goebl, & Widmer, 2005). An important and recent development is the design and implementation of monitoring tools that support the learning process by measuring the instrumental gestures and posture of for example string players (e.g. Schoonderwaldt, Hansen, & Askenfeld, 2004; Ng, Larkin et al., 2007; Schoonderwaldt & Wanderley, 2007). In other words, being able to give visual feedback on music performance and on learning is a rather common goal, and it has been used in many different applications.

The introduction of visual feedback in music instrument lessons by using monitoring technologies has indeed several important advantages. A first advantage is the ability to complement the interpersonal feedback processes between teacher and learner. Interpersonal feedback always involves a certain ambiguity (Welch et al., 2005) which real-time monitoring systems can ignore to a certain degree. This more 'objective' feedback may reduce the possible misinterpretations of discontinuous (e.g. comments after playing) or even of continuous (e.g. the teacher playing or singing along) feedback from the teacher by providing students and teachers with a more immediate and unambiguous feedback.

A second advantage of visual feedback is that it can contribute to the students' goal imaging, their motor production skills and finally, their self-monitoring skills. By engaging students in an interactive loop with the visual feedback, they get stimulated to autonomously set and adapt goals. Motor production can then be fine-tuned on the basis of self-monitoring processes in which these goals and motor production are compared on the basis of feed forward models and intrinsic feedback.

However, despite the possible benefits, the integration of monitoring tools in instrumental didactics must be undertaken with some precautions. In the first place, it is important that the use of these technologies goes further than merely providing information. Providing students with feedback on their playing by means of monitoring technologies can still support traditional ways of teaching that consolidate a teacher-centered approach. What matters is the way in which this information is used to help students developing the necessary self-monitoring skills.

It should be added here that the visualization of aspects of the learners' performance as a continuous concurrent feedback is not undisputed. Although its essential role in skill acquisition is acknowledged and shown in different studies (Shea & Wulf, 1999; Wulf, Shea, & Matschiner, 1998), other studies show that continuous concurrent feedback can also degrade learning (Schmidt & Wulf, 1997).

A possible explanation for the differences in findings on the effect of continuous feedback might be that it depends on how the feedback is presented and to which degree it fits both the learning context and the learners. Augmented feedback needs to engage learners in an immersive experience that enables them to get intrinsic feedback and that motivates the learner. Furthermore, it must be used in situations were users find it difficult to use intrinsic feedback because of a lack of experience (e.g. no experience with improvising). It must be avoided that the learner becomes dependent on the feedback. Therefore, we believe that it is important to develop the technology-enhanced learning tool in a proper pedagogical context and in combination with concepts that justify its development and testing at long term. With the Music Paint Machine, these concepts are rooted in constructivist pedagogy, the theory of embodied music cognition and how mediation technologies relate to the human body, and in concepts of flow and presence, which allow the probing of the subjective experiences that may determine the learning effect.

8.9.3 The Music Paint Machine: exploring a novel way of monitoring

The Music Paint Machine complements existing applications such as developed in the project I-Maestro (Ng, Larkin et al., 2007) or sound visualization systems (e.g. Ferguson et al., 2005) by exploring new ways of visualizing monitoring data in agreement with informed theories of music cognition and pedagogy, such that a visual feedback system can be optimized for enhancing imagination and musicality. The Music Paint Machine introduces a game-like experience in which the musician creates an artistic output based on the music that is played and the movements that are used. Starting from the viewpoint that a symbolic representation of objective feedback on a computer screen might just as well give rise to a disembodied way of dealing with the feedback, the Music Paint Machine provides students and teachers with feedback that is also based on objective measurement of sound and movement but is represented as a creative output (the painting). Seemingly monitoring is not the primary use. However, because of the mapping of music and movement to a visual representation, and because this mapping is based on a monitoring of the performance, monitoring is an essential element. The slightest variations in movement and sound affect the visual output and thereby address the musician's goal setting, motor production and self-monitoring. For example, when the musician's goal is to draw a straight line that becomes thicker, but the output shows a slightly curved line, self-monitoring is essential to adapt motor production (playing technique) in function of the goal. This may cause a breakdown in the experience and call for a reflective moment during which it becomes apparent that playing louder caused a small change in pitch. In this case, self-monitoring is conscious. However, when the musician is completely absorbed in the act of creating a visual output with music and movement, he/she will engage in an interactive loop between actions and visual output. Self-monitoring will be based on the unconscious processing of intrinsic feedback. As long as the player's skills and the challenge remain in balance, dynamically setting goals and adapting motor production in function of these goals will, on the one hand, be based on the direct perception of task-related feedback and, on the other hand, rely on the skills of the musician. Over time, we believe that the frequent use of the Music Paint Machine may establish a set of action–perception couplings that form part of the musician's toolbox of creativity. Challenged by the myriad of possibilities for the transformation of movement and sound into an artistic output, musicians will be pushed to the boundaries of their musical abilities.

8.10. Conclusion

In this paper, we described our approach of designing a technology-enhanced learning tool, called the Music Paint Machine. This tool aims at enhancing music performance skills by using concurrent visual feedback that is based on real-time monitoring of audio and movement. The approach is practice-based and has a firm ground in the theoretical frameworks of embodied music cognition, of flow and presence, and of educational constructivism. Furthermore, it involves an empirical framework that is set up to initiate an iterative process between theory, practice and soft- and hardware development. In this empirical framework, the collaboration between researchers, teachers and students is very important. We presented the first series of experiments that probe the subjective experience of students and their evaluation of the application's didactic potential. The results show that the Music Paint Machine copes with positive assessments of flow and presence, which suggest that it potentially may become a tool that enhances music learning.

CHAPTER 9

Interacting with the Music Paint Machine: Relating the constructs of flow experience and presence

NIJS, L., COUSSEMENT, P., MOENS, B., AMELYNCK, D., LESAFFRE, M. & LEMAN, M. (2012). Interacting with the Music Paint Machine: relating the concepts of flow experience and presence. *Interacting with Computers*, 24, pp. 237-250.

Abstract

In this paper we report on the results of an experiment on the experience of flow and presence while engaging with an interactive music system, the Music Paint Machine. This music system provides a game-like environment in which a musician can create a digital painting by playing an acoustic musical instrument, by moving the body in different directions, and by selecting colours using a pressure mat. The experiment aimed at getting a better insight into the possible relationship between flow experience and presence. Based on the definition of flow as a combination of the highest level of presence (presence-as-feeling) and a positive emotional state (Riva et al., 2004a), we hypothesized that presence has a predictive value for flow. Sixty-five musicians, both amateur and professional, participated in the experiment. Flow experience was measured with the Flow State Scale (Jackson and Eklund, 2004). Presence was measured with an in-house designed presence questionnaire. Results showed a significantly strong correlation between flow and presence. Moreover, the scores for presence significantly predicted the Flow State Scale, and explained a significant proportion of variance in the Flow State Scale. Furthermore, many significant associations were found between flow and presence variables, among which the most significant were the strong correlation (Spearman's rank) between the naturalness of using the system and the Flow State Scale and between the feeling of non-mediation and the Flow State Scale.

9.1. Introduction

In the field of music, interactive computer systems have become increasingly important in domains such as music performance and music education (e.g. Ng and Nesi, 2008; Finney and Burnard, 2009; Nijs et al., 2012). An important goal of these systems is to provide the user with an optimal experience, that is, an experience in which the user gets fully immersed, or deeply involved with the intended activity. In general, it is believed that the transparency of the used technology provides the basis for such an optimal user experience. This means that, when engaging with the interactive system, the user can focus on the goal ("what"), rather than being preoccupied with the means of how to achieve the goal ("how") (e.g. Clark, 2008; Leman, 2007).

In recent work, attention has been devoted to embodied ways of engaging with music (Leman, 2007). In this approach, interactive systems are conceived as extensions or prolongations of the human body. The body is called the natural mediator because it mediates the connection between environment and experience. The technological extension is called the artificial mediator, because it provides access to an artificial (or digital) environment and its associated experience. Access to music is typically mediated by tools, such as music instruments, or interactive systems (from hyper instruments to autonomous agents). From the viewpoint of embodied music cognition, the design of interactive systems should be aiming at the optimization of an embodied engagement with a musical environment that is not accessible without such a system. When successful, interactive systems form the basis for musical expression and musical meaning formation.

The Music Paint Machine is an example of a technology-enhanced learning tool that aims at providing a meaningful learning experience. As an interactive music system for music education, its ultimate goal is to optimize the learning process. Such technologies challenge pedagogical systems and offer a means to think about music education. Moreover, by integrating state of the art technologies, interactive music systems offer new possibilities for supporting the scientific endeavour to understand the processes that underlie an engagement with music. This leads to an increasing importance of user-oriented approaches in which the computer-mediated musical experience of both musicians and listeners are studied (Leman et al., 2010). However, to see whether and, if so, how interactive systems effectively support a direct involvement with music, the user experience of listeners and performers needs to be measured. This is often problematic, because subjective experience is often loosely defined and interchanging terms are used for phenomena that may be different (Nacke and Lindley, 2008).

A possible contribution to the conceptualization of subjective experiences is the investigation of the relationship between different existing constructs that aim at defining subjective experience. Two important constructs are flow and presence. Flow experience is an optimal experience in which the subject is completely immersed in an activity and fully concentrated on the task at hand. It is characterized by a sense of control and pleasure based on a subjectively experienced match between challenges and skills (Csikszentmihalyi, 2008). In contrast, the experience of presence is less agreed upon (Van Baren and Ijsselsteijn, 2004). Here we follow Riva and colleagues in their definition of presence as the non-mediated perception of successfully transforming intentions in action (Riva, 2008).

The relationship between flow and presence has been elaborated on in different studies. For example, presence has been conceived of as a kind of flow experience (e.g. Jacobson, 2002; Draper et al., 1998) or as a facilitator (Park and HWang, 2009), a prerequisite (Takatalo et al., 2002) or an enhancing factor for flow (Novak et al., 2000). Riva et al. (2004a) define flow as the result of the link between the highest level of presence-as-feeling, with a positive emotional state. However, there are only a few studies in which this relationship is investigated on the basis of empirical evidence. For example, Park and Hwang (2009) investigated how different types of immersion affect on online game addiction. These authors found that both presence and flow play a significant role in online game addiction. Their findings suggest that flow mediates the relationship between presence and online game addiction. Chertoff (2009) explored the relationship between flow and presence through measuring users' reported flow and presence in a virtual environment that, based on its experiential design, was expected to stimulate flow. According to the findings of this author, flow neither enhances nor mediates presence. Rather it is the combination of the experiential design and flow that generates a larger general experience that shows a positive correlation with presence.

In the present paper, we report on an empirical study that uses an interactive system as an instrument to study the relationship between flow and presence. In particular, we present findings from a study with the Music Paint Machine, which is an interactive music system that allows musicians to make a digital painting by playing music on an acoustical instrument and by moving on a coloured pressure mat. As a first empirical step, we probed the experience of musicians (n = 65) when engaging with the system (Nijs et al., 2012, in press). The measurement of these experiences consisted of two separate questionnaires, namely, the Flow State Scale (Jackson and Eklund, 2004), and an in-house designed questionnaire on presence based on the Witmer & Singer Presence Questionnaire (Witmer and Singer, 1998; Witmer et al., 2005). The questionnaire-based measurement of flow and presence was used because we believe that the Music Paint Machine draws upon a unique relationship between musician and instrument, in which both flow and presence are highly relevant (Nijs et al., 2009, in press). Based on these measurements, our goal is to find relationships between the musicians' experiences of flow and presence, while interacting with the Music Paint Machine.

This paper is structured as follows: first we introduce the Music Paint Machine, describing the system and relating it to the constructs of presence and flow (Section 9.2). An explanation of the system is given, followed by an elaboration of the role of presence in interacting with this system. Then we describe an empirical study that was conducted with 65 musicians (Section 9.3), followed by a conclusion (Section 9.4).

9.2. The Music Paint Machine

In this section we explain the system and the way it is related to flow and presence.

9.2.1. Explanation of the system

The Music Paint Machine is an interactive music system that allows a musician to make a painting on a computer screen by playing an acoustic music instrument and by moving on a coloured pressure-sensing mat. In this way, the musician engages in an interactive loop between playing music and moving on the one hand and the visual output on the other hand.

The hardware and the software of the system are developed in our research centre through 'a spiral collaboration' (Addessi, et al., 2004) between researchers with backgrounds in music education, computer science and interactive visual art, and an engineer. An elaborated description of the design methodology and the hardware and software of the system is presented in Nijs et al. (2012, in press). Here we shortly describe the system as presented in figure 8.4.

Different hard- and software components such as for example inertial sensors and a Max/Msp1 pitch-tracking object are used to monitor the musician's playing. The music that is played and the movement of the musician's torso and feet are tracked, analyzed and mapped to the visual parameters that constitute the digital painting. An overview of the mapping is presented in figure 8.5.

An important aspect of the Music Paint Machine's mapping (from audio and movement to visual) is determined by the way in which the music instrument and the musician are both united into a higher order entity (Nijs et al., 2009, in press). This unity of musician and instrument becomes the controller of an interactive system that provides feedback on a screen. In contrast to many existing interactive music systems (e.g. Wii Music, Guitar Hero), the acoustical music instrument is not replaced by an electronic device that is either completely different (e.g. the Wii remote) or either a simplified version of existing acoustic instruments (e.g. the guitar of Guitar Hero).

9.2.2. The Music Paint Machine, flow and presence

The Music Paint Machine provides a multimodal environment that mediates the musical experience of the musician. While "painting with body and music", the musician engages in an interactive loop between body movement, sounding music, and visual output. In this way, the system constitutes a particular activity that shapes the experience of the musician. As a learning tool, the Music Paint Machine aims at supporting the development of musical creativity, at the stimulation of an embodied understanding of music and at the development of an intimate relationship with the musical instrument (Nijs et al., 2010, in press).

Probing the musicians' experience with questionnaires is an important part of the iterative design process that steers the development of the Music Paint Machine into a practice-based technology-enhanced learning tool (Nijs et al., in press, 2012). After all, it is assumed that the possible effectiveness of this interactive system depends to an important degree on its ability to provide learners with a powerful learning environment that stimulates learning by invoking an optimal experience (e.g. Shernoff and Csikszentmihalyi, 2009).

9.2.2.1. The Music Paint Machine and flow

The three pedagogical goals that underpin the design and use of the Music Paint Machine are related to the construct of flow.

The first pedagogical goal concerns the development of musical creativity. Optimal experiences such as flow have often been acknowledged as fundamental to the development of (musical) creativity (e.g. Addessi and Pachet, 2005; Csikszentmihalyi, 1990). The Music Paint Machine aims at inducing such optimal experiences by providing students with an immersive experience of playing with musical parameters, body movements and visualizations. By means of explorative sessions and specific exercises that are integrated into a learning path, students are stimulated to explore and experiment with music in order to develop a creative use of the different musical parameters namely loudness, duration, pitch and articulation. It is assumed that the occurrence of a flow experience while interacting with the Music Paint Machine will invoke a sense of playfulness with the different musical parameters. This is expected to have a positive effect on musical creativity. Indeed, playfulness in general has been related to flow experience (e.g. Webster et al., 1993; Woszczynski et al., 2002), and playfulness with musical parameters has been considered an important aspect of musical creativity (e.g. Deliège and Wiggins, 2006). Moreover, learning to be playful with musical parameters is linked with learning how to improvise (Kratus, 1991). Improvisation can be considered as an essential component in the development of musical creativity (e.g. Strobbe and Van Regenmortel, 2010).

The second pedagogical goal concerns an embodied musical understanding of which we believe that it is stimulated by flow experience. Such an understanding is said to originate from the ability to feel the music from within (e.g. Bowman, 2004), that is, through the bodily sensing, feeling and experiencing of the musical sounds (Shepherd, 2002). It is assumed that, through a process of corporeal imitation, learned schemata of action-perception couplings are used to transform patterns of sound into corporeal articulations (Bowman, 2004; Leman, 2007). In this way it becomes possible to corporeally resonate with the music and to rely on the experiential – corporeal – basis to give meaning to the music and to develop musical understanding. Such corporeal attunement with the music is characteristic for an embodied interaction with music. It is an experience in which the musician participates in a direct and engaged way in the musical environment he or she creates throughout a performance (Dourish, 2004). Participating in this way in the musical environment is based on a direct perception of the musical stimuli and on a skill-based coping with the challenges that arise from the complex interaction within this environment (Nijs et al., 2009, in press). Direct perception and skill-based acting are two sides of one coin and can be related to several dimensions of flow experience, namely a balance between the perceived challenges and one's skills, immediate feedback, the sense of control and the merging of action and awareness. The Music Paint Machine is designed to create an environment that, through the facilitation of direct perception and skill-based acting, stimulates an embodied interaction. While the digital painting is meant to capture the focal awareness of the musician, many aspects related to musical parameters may reside in subsidiary awareness and become elements of tacit knowledge (Polanyi, 1958). Embodied understanding here derives from what Polanyi calls "indwelling", that means, the active engagement of the body with the factors that comprise our subsidiary awareness. Flow experience, devoid of disconnected observation and control, is rather characterized by an inhabited interaction in which a person is so focused on the task at hand that action and awareness merge. We believe that his may facilitate the indwelling, or knowing from within, and thereby may invoke a powerful implicit learning process.

The third pedagogical goal concerns the establishment of an optimal relationship with the music instrument (Nijs et al., 2009). We believe that flow experiences may foster the optimal relationship with the music instrument. It is assumed that every time a musician experiences flow, the music instrument becomes transparent in use, i.e. it disappears from consciousness while performing. At that moment the instrument is temporarily experienced as a natural extension of the body. In the beginning of the learning process, the flow experience may only have a short-term effect on the relationship between musician and musical instrument. Yet, a repeated flow experience might render the mental schemes that accompany the feeling of unity with the musical instrument more permanent, resulting in a long-term intuition, even when the instrument is not at hand. The Music Paint Machine might contribute to such a repeated occurrence of flow experience while playing the musical instrument.

Despite the fact that activities in which flow experiences occur are often mediated by a material artefact (e.g. a computer, or a music instrument), the vast literature on flow experiences shows a considerable lack of attention to the role of the body as the natural mediator of human experience that can be extended with technologies such as musical instruments and new media (e.g. Finneran and Zhang, 2003; Romero and Calvillo-Gámez, 2011). A possible way to elaborate on the role of bodily engagement and the impact of mediating technologies on this engagement is to follow the approach of Riva and colleagues (e.g. Riva et al., 2004a,b) who defined flow as the combination of presence and a positive emotional condition. In the next section we consider this approach in more detail, with regard to the interaction with the Music Paint Machine.

The design of the Music Paint Machine aimed at facilitating the flow conditions. Therefore particular attention has been devoted to three flow dimensions, namely, the balance between skills and challenges, the immediate and unambiguous feedback, and clear goals (Chen et al., 1999). The mapping of pitch to vertical position on the screen can be adapted to the ranges of notes a musician can play. Similarly, stroke thickness can be adapted to the loudness range of the musician. In this way the system enables the balance between skills and challenges and accordingly a skill-based playing. Next, the immediate and unambiguous feedback on the screen is the result of the musician's playing (sound and movement). It is assumed that the straightforward nature of the mapping that underlies the transformation from sound and movement into the visual domain might stimulate the direct perception of task-related stimuli. Finally, it is possible to define one's own goals (e.g. merely drawing a series of lines in one colour, drawing a complex pattern of colours and geometrical figures or drawing a concrete image such as a boat on the sea) or to perform specific drawing tasks, provided by, for example, a teacher. In both cases, the system allows activities that are characterized by clear goals. It is assumed that the abovementioned system characteristics might facilitate an embodied interaction and induce a flow experience.

Measuring the subjective experience of musicians interacting with the Music Paint Machine is an important step in verifying whether the system can fulfil its role as a learning tool. In the field of music and music education, the construct of flow has been used to study learner's subjective experience (e.g. Custodero, 2002, 2005; MacDonald et al., 2006; St John, 2006). However, studies that use the flow construct to study the experience of musicians while being engaged with an interactive music system are still scarce. Addessi and colleagues investigated children confronting the Continuator (e.g. Addessi and Pachet, 2005; Addessi et al., 2006), a machine with a piano interface that engages in a dialogue with the player by producing musical phrases as a stylistic continuation of user input. Studies with the Continuator use flow related behavioural measures, namely the flow indicators (Custodero, 2005) and an observation grid based on the emotive tones described in the Theory of Flow (Addessi et al., 2006).

Although the measurement of flow experience may capture an important aspect of the learners' experience, we believe that the construct of flow may not be sufficient to capture the mediating role of the body and its technological extensions. It is assumed that the measurement of presence might contribute in a significant way to understanding the interactive processes and their bodily basis, especially when engaging with an immersive multimodal interactive music system such as the Music Paint Machine.

9.2.2.2. The Music Paint Machine and presence

Measuring the sense of presence while engaging with an interactive music system informs on the degree to which one is bodily engaged during the performance of a task. It is assumed that the sense of presence is rooted in an unconscious mechanism, namely presence-as-process, which allows controlling behaviour on the basis of an unconscious differentiation between the inner and outer world (Riva et al., 2004a,b).

According to Riva et al. (2004b), presence is a layered process that relies on a coherent collaboration of bodily sensations, perception and cognition to keep attention focused on the activity. Three layers, called proto presence, core presence, and extended presence are hierarchically structured, following the hierarchical relationship of Damasio’s levels of self (Damasio, 1999). Each layer deals with the separation between the internal (self) and external (non-self) world and is hypothetically related to a level of consciousness. Proto presence is about the bodily being in the world (self vs non-self) and is only achieved when the self is able to use the body for enacting intentions in the external world. Core presence is related to the differentiation between planned actions and actual actions (self vs present external world). At this level, presence is only achieved when it possible to select and respond to task-related elements in the environment. Extended presence is related to the significance of the activity for the self (self relative to the present external world).

In view of an embodied apprehension of flow, it is instructive to consider proto presence in more detail. The more the internal world (self) is focused on the body, the more it is different from the external world. Being in the body results from unconsciously experiencing the self as being able to use the body for coping with the challenges in the external world. At this level of presence, the sensorimotor coupling of action and perception plays a defining role. Proto presence occurs when the coupling between actions and perception is perceived as matching, that is when the outcome of an action satisfies the anticipated results. This is always accompanied by the bodily sensation of something affecting the border between self and non-self. Importantly, whatever has the most impact on the body will be the focus of this level of presence, and it will therefore be experienced as non-self. According to Riva et al. (2004a,b) a maximal sense of presence, namely, presence-as-feeling or the feeling of being “there”, occurs when the content of every level of consciousness is the same, namely the external world (“there”).

To better understand how presence is related to a musical experience with the Music Paint Machine, it is necessary to examine in more detail the nature of the processes that underlie music making. Through his actions, the musician creates a musical reality that can be considered as the actualization of an imaginary world, a virtual reality that is constituted by the musician's musical intentions and representations. For the musician, creating this musical reality is characterized by the coupling of two representational spaces (Leman, 2007).

The first representational space is called the "inner space", or the representation of the world "inside us". It contains a repertoire of gestures, that is, traces of motor activity in memory that relates to the sensing and execution of movements in function of goals. With regard to music, these gestures are derived from previous experiences with music through, for example, rehearsals and previous performances. A distinction is made between gross-motor gestures and fine-motor gestures. The gross-motor gestures have a social communicative basis, and they are required to play music in an expressive way, so that the music can affect other persons. For example, they can be larger sequences of notes that address a particular emotional quality. The fine-motor gestures have a sensorimotor basis. These gestures rely on the repertoire (because they are rehearsed), but they are also largely dependent on a direct and immediate feedback from the environment. They are required to play a specific musical instrument, for example, to control the fingers and the lip tension in a coordinated way in order to play a single note on the trumpet.

The second representational space is called the "outer space", or the representation of the world "outside us". This space is constituted by incoming sensory information from the interaction with the environment. It is based on the feedback of the musical instrument, the sonic structure of the music, the audience, the acoustics of the room, and other possible constituents.

The coupling of both spaces allows perceiving the musical reality from the viewpoint of intentional actions. Based on the anticipatory model and the incoming sensory information, actions are monitored and evaluated in relation to goals.

Presence is exactly this process that monitors actions in function of an intended outcome. A maximal sense of presence occurs when the three layers of presence are integrated and all levels of consciousness share the same content. This means that, to immerse in the musical reality and experience the sense of presence, the musician must be able to attune to the music at the level of bodily sensation, perception and cognition. However, given the complexity of the musical environment and the fact that a musician has to deal with a series of competing signals that arise from the interaction with the different elements of the musical environment, this is not obvious. Whatever stimulus has the strongest impact on the body, it will determine the content of proto consciousness and influence proto presence. Ideally, the musician can immerse in the music through a bodily attunement with the music. In this case the musician can focus on signals from the music and deal with the musical goals (interpretation, expression). This implies that the content of core consciousness will be the music. As long as the music unfolds in accordance with the musical goals, this will not change and core presence will be dealing with the signals from the music. However, when the mediating artefacts such as the musical instrument have the strongest impact (e.g. because of technical difficulties, a wrong note or a squeek), the musician instead has to be preoccupied with the means to realize these goals (executive strategies) will shift attention from the music to the mediating artefact that caused this shift. It will no longer be possible to keep core consciousness focused on the music and immerse in the musical reality. Instead the musician will have to attend to the signals that arise from the interaction with the mediating artefact.

The above theory was regarded as highly relevant for the Music Paint Machine. By transforming movement and sound into a visual output, the Music Paint Machine creates an "augmented" musical environment and thereby affects a musician's involvement in this environment at the level of sensation, perception, and cognition. We assume that the Music Paint Machine affects the musician's sense of presence while painting through movement and sound.

First, the auditory-motor loop that underlies the process of making music is augmented with the visual modality through which both auditory and motor aspects are represented on a computer screen. The visual feedback augments the created musical world or auditory reality with a visual output (the "painting"). Because what is happening on the screen is the result of the musician's actions, the visual output provides extra sensory information that enables the musician to monitor whether the intentions in action are successfully transformed. Starting from the viewpoint that presence is a form of monitoring of action and experience that enables the musician to discriminate between self-determined and world-determined changes in incoming sensory information (Riva et al., 2006; Russell, 1996), we assume that the Music Paint Machine affects core presence through the feedback it provides. Moreover, using the system requires specific movements and thereby engages the body in ways that can be unusual with regard to "normal" playing. Using the feet to choose the colours or twisting and bending the torso to respectively choose drawing direction and influence colour transparency, leads to additional movement patterns. It is assumed that this might stimulate a bodily focus on the task and thereby affect proto presence.

Second, and related to the monitoring of one's actions, using the Music Paint Machine may affect the creation of action perception couplings. These couplings are crucial for determining the extent to which intentions are successfully enacted, so that the sense of presence can occur (Zahorik and Jenison, 1998).

Musicians always have certain goals in mind (e.g. making crescendo) but sometimes, unconsciously, fail to realize this goal in the sound energy (increasing amplitude). Failure might be attributed to listening skills or to attention, but when this repeatedly happens, a "wrong" action perception coupling can be established. Adding visual information about the musician's actions might point at this unnoticed discrepancy between intended and actual results of sound production by providing additional – inconsistent – information. The visual feedback informs the musician that certain intentions are not successfully enacted. Accordingly the musician might correct his or her actions to make all sensory information consistent. Moreover, this process of adapting one's actions in order to render the auditory, kinesthetic and visual feedback consistent can become an unconscious monitoring process. In this way, the Music Paint Machine may contribute to the establishment of the necessary fine-tuned action perception couplings that constitute the musician's interaction with the musical world and that underlie the musician's fine-grained control over the instrument. Again, we assume that this may affect the sense of presence through the stimulation of both proto and core presence.

Third, by introducing body movement and sound as controllers of the system, the computer screen not only serves as a mirror of a performance (sound and movement) but, additionally, functions as a digital painting canvas that appeals to the musician's creativity and imagination to create a digital painting. In this way, the Music Paint Machine affects the goals of the musician, who in addition to his musical goals can try to realize effects in the visual domain. It is assumed that this invitation to be creative might affect the meaningfulness of the activity for the musician and thereby contribute to extended presence.

9.3. Empirical study

9.3.1. Method

9.3.1.1. Participants

This study involved 65 musicians, both professional and amateur. They were recruited by advertisements on social network sites and in different music schools. Furthermore, a website was created to inform possible participants on the experiment and to organize the sessions. All participants were informed about the procedure and participated on a voluntary basis.

Two-thirds (66%) of the participants were female. Their average age was 23 years and about two thirds (65.6%) of them were under the age of 25. Participants' main instruments were flute (27.7%), clarinet (20%), saxophone (18.5%) and violin (13.8%) and other instruments (20%). They have been playing their instrument for 1– 9 years (58.5%) or longer (41.5%). One fifth of (20%) the participants were professional musicians and teaching in a music school. The other participants were amateur musicians, most of them (75%) still following instrumental lessons.

9.3.1.2. Materials and setting

The material that was used for the experiment included the Music Paint Machine and its components (i.e. coloured pressure sensing mat, computer, motion sensor, clip on microphones). The computer screen was projected onto the classroom wall or screen using a beamer. Two digital video cameras were used: one video-taped the musician, the other the screen. Experiments were mostly conducted in music schools, involving 63% of the participants. Amateur musicians who no longer followed instrument lessons and therefore were not able to attend the sessions in schools, and most teachers tested the Music Paint Machine at the research lab. Apart from the different locations, material, setup and procedure were identical.

9.3.1.3. Procedure and task

The experiment consisted of three sequential parts: (1) completing a background and personality questionnaire, (2) performing a task with the Music Paint Machine, and (3) completing a questionnaire that probed, in the first place, the participants' subjective experience while performing the task and, in the second place, the way they evaluated the didactic potential of the system.

In the first part of the experiment, a background questionnaire was administered to the participants prior to the testing. They were requested to answer general questions related to age and gender. They also had to specify, using a non-forced seven-point Likert scale, to what extent they agreed with statements about their musical background and their computer use.

In the second part of the experiment, participants performed a task with the Music Paint Machine. Firstly, they were shortly informed on how to use the system. In this way they could learn about its mapping. This step also included the calibration of the system in accordance with the skills of the player, such as the adaptation of the screen resolution to the range of notes the participant could play or the adaptation of the brush size to the dynamical range of the participant's playing capabilities. Finally, the participant performed a task, formulated as follows: "Please create one or more paintings on the screen, by playing music with your instrument and by moving on the coloured mat". It was emphasized that they could draw whatever they wanted, whether figurative or abstract and that the label of bad or good was not applicable to the paintings or the music played. Participants were given ten minutes to perform the task. This part of the experiment was videotaped.

During the third part of the experiment, participants were asked to complete a questionnaire consisting of three sets of questions that aimed at (1) measuring the quality of their subjective experience while playing music and making a painting with the Music Paint Machine and (2) learning about the way the participants evaluated the didactic potential (dependent variables) of the system after having experienced playing with it (independent variable). The first set comprised the questions of the Flow State Scale (Jackson and Eklund, 2004). The second set of questions was designed in-house on the basis of the theoretical presence determinants as defined by Witmer and Singer (1998). The third set comprised questions related to the role of the visual feedback, the possible supportive role of the system for learning how to play an instrument or for developing improvisation skills. Although the last set of questions is not directly related to the quality of the subjective experience, the way participants evaluate the didactic potential of the system is related to the meaningfulness of the experience, which is assumed to play a role in the experience of presence (Witmer and Singer, 1998).

9.3.1.4. Measures

The Flow State Scale questionnaire (FSS).

The Flow State Scale (Jackson and Eklund, 2004) probed the participants' experience with the system by means of 36 questions that can be grouped into nine dimensions of flow experience (Csikszentmihalyi, 1990). These nine dimensions can be grouped into antecedents, characteristics and consequences (Chen et al., 1999). The scores of these dimensions are combined to measure an overall scale (FSS) that represents the flow state of the participant (see Table 9.1).

Table 9.1. Flow dimensions and categories as elaborated by Csikszentmihalyi (2008).

Flow			
FSS	**CATEGORIES**	**DIMENSIONS**	
	Antecedents	Challenge/skill balance	*personal skills are well suited to given challenges*
		Clear goals	*objectives are clearly defined*
		Unambiguous and immediate feedback	*one knows instantly how well one is doing*
	Characteristics	Merging of action and awareness	*one-pointedness of the mind*
		Concentration on the task at hand	*irrelevant stimuli disappear from consciousness, worries and concerns are temporarily suspended.*
		Sense of control	*the ability to take control of the situation without any conscious effort*
	Consequences	Altered time perception	*time passes differently from normal*
		Loss of self-consciousness	*the concern for oneself disappears while engaging in the activity*
		Autotelic experience	*enjoying the activity for its own sake*

The original Flow State Scale questionnaire was translated into Dutch. The translation procedure was as follows: first, two professional translators and two bilingual researchers, familiar with the theory on flow and experienced in questionnaire design, worked independently to translate the original English version into Dutch. Second, a third bilingual researcher, also familiar with the theory on flow and experienced in questionnaire design, combined these versions into one version. Finally, questions were translated back into English and adjustments were made. To allow for more variability in the responses and to keep the same scale granularity for both the flow and presence questionnaires, items were measured on a non-forced seven-point Likert scale instead of the usual five-point Likert scale. Answers ranged from "completely disagree" to "completely agree".

In-house designed presence questionnaire (PSS).

Our presence questionnaire is a first attempt to develop a presence questionnaire in the domain of interactive music systems. After the examation of different existing questionnaires (see http://www.presence-research.org/Questionnaires.html), we decided to take the Presence Questionnaire (PQ), developed by Witmer and Singer (1998), as our starting point. This was done for several reasons. First, this questionnaire was designed to be valid across media and content. Second, the theoretical factors the PQ was elaborated on, namely control, distraction, sensory experience and realism of the system (see Table 9.2), were evaluated as appropriate factors to define the interaction with the Music Paint Machine.

Table 9.2. Witmer & Singer's presence factors that were used to design the presence state scale questionnaire for this experiment.

Presence		
PSS	PRESENCE FACTORS	
	Control Factors	Degree of control Immediacy of control Anticipation of events Mode of control Physical environment modifiability
	Sensory Factors	Sensory modality Environmental richness Multimodal presentation Consistency of multimodal information Degree of movement perception Active search
	Distraction Factors	Isolation Selective attention Interface awareness
	Realism Factors	Scene realism Information consistent with objective world Meaningfulness of experience Separation anxiety/disorientation

Third, despite Slater's comments to the validity of the PQ (Slater, 1999), the fact that the PQ questions measures people's responses to various aspects of the system was not seen as a disadvantage, since the experiment also aimed at finding out what characteristics of the system are determining aspects in relation to the experience of presence. It is assumed that the way in which people feel or experience their own responses to the system, determines the possible experience of presence. After all, through the activity it initiates, the system creates a specific environment and thereby mediates its user's musical experience on the basis of its specific characteristics. The ability to respond to these characteristics determines the degree to which one is able to successfully transform intentions into actions with the system. By asking participants to report on their perceptions of the environment and on their interactions within this environment, the questionnaire attempts to capture a multitude of variables that influence the experience of presence.

Because not all of the items of the Witmer & Singer Presence Questionnaire were suitable to the particular conditions of the experiment (e.g. "How compelling was your sense of moving around inside the virtual environment?"), we selected the appropriate items and adapted them to suit the particular condition of interacting with the Music Paint Machine. In order to increase the identification of the participants with their answers and to give them the opportunity to reflect on their personal experience and perceptions, statements were mainly formulated from a first person perspective. In Appendix A, we present the Witmer & Singer questions and the questions of our questionnaire. Participants were asked to rate their (dis)agreement with the statements on the basis of a non-forced seven-point Likert scale from "completely disagree" to "completely agree".

9.3.1.5. Statistical analysis

Statistical analysis of all questionnaire data was performed using SPSS 19.0. The overall aim of the analysis was to gather knowledge on the users' experience while being engaged in the interactive loop between playing music, moving and drawing when using the Music Paint Machine in it's explorative modus (no specific drawing or musical tasks). In this paper we report on the results with regard to flow, presence and their possible relationship.

Flow

First, internal consistency was tested for with the Cronbach Alpha test. Second, scores for the nine flow dimensions and Flow State Scale were calculated following the procedure as prescribed in the manual of the Flow State Scale (Jackson and Eklund, 2004). Additionally we calculated scores for the three stages of flow as outlined by Chen et al. (1999). Third, a descriptive analysis was performed on both measured variables, namely the score for individual items (e.g. enjoyment, focus of attention) and calculated variables, namely the mean score for groups of items (flow dimensions) and total scores (Flow State Scale).

Presence.

For the in-house designed presence questionnaire, a similar procedure as for the Flow State Scale was followed. First, internal consistency of the questionnaire was tested using Cronbach's alpha. Second, a score for presence was determined by calculating an overall mean score (PSS). To calculate this overall presence score, the scores of certain items (e.g. "While performing, I paid attention to my movements", "While performing, I paid attention to what happen around me", "Using this system requires a great mental effort") were reversed to obtain a score that is representative for the sense of presence (e.g. a high score on cognitive load would increase the overall score of presence but is not representative for the sense of presence). Third, a principal component analysis was used to extract determining factors and to allow for an analysis on different levels (items, factors, scale) as was done for the Flow State Scale.

Flow and Presence.

To test for a possible relationship between flow and presence, several statistical procedures were followed to get a detailed view on the relationship between the constructs of flow and presence. In our analyses, we opted for a strong significance level (p = .001). First, a simple linear regression was performed on the FSS (dependent variable) and the PSS (independent variable). If flow is defined as a combination of presence and a positive emotional condition, then it is assumed that the PSS has a predictive value with regard to the FSS. Second, a multiple linear regression with the FFS as independent variable and the extracted presence components as dependent variables was performed. Here the goal is to scrutinize how different aspects of presence are related to the state of flow. Third, we performed a canonical correlation analysis to investigate how specific aspects of flow are related to specific aspects of presence and to look for common features.

9.3.2. Results

9.3.2.1. Flow

A Cronbach's alpha test (α = .921) confirmed the internal consistency of the questionnaire.

The scores of the Flow State Scales varied from 3.44 to 6.78 on a seven-point Likert response format from completely disagree to completely agree. The moderately high overall mean (M = 5.15, SD = 0.74) indicates that the Music Paint Machine is likely to have the potential to turn the experience of playing music, moving and drawing, into an optimal or flow experience. Descriptive analysis on the level of flow dimensions showed a moderately high score for dimension 1 (challenge/skill balance). The dimensions 5 (concentration on the task at hand), 8 (loss of self-consciousness) and 9 (autotelic experience) have the highest score. These results indicate that the Music Paint Machine has the potential to elicit a fun experience that fully captures the musician's attention. In Table 9.3, we present an overview of the scores for the Flow State Scale and the different dimensions and categories.

Table 9.3. Mean and standard deviations for the flow dimensions, categories and scale.

Flow		*M*	*SD*
DIMENSIONS	10. Challenge/skill balance	**5.21**	**.90**
	11. Clear goals	4.18	1.14
	12. Unambiguous and immediate feedback	4.38	.94
	13. Merging of action and awareness	4.09	1.46
	14. Concentration on the task at hand	**6.08**	**.86**
	15. Sense of control	4.67	1.27
	16. Altered time perception	5.18	1.21
	17. Loss of self-consciousness	**5.80**	**1.03**
	18. Autotelic experience	**5.98**	**.79**
Antecedents		4.59	.80
Characteristics		4.94	.94
Consequences		5.65	.72
Flow State Scale		5.15	.74

9.3.2.2. Presence

A Cronbach's alpha test generated a rather mediocre but – in view of the exploratory character of the study – just acceptable score ($\alpha = .638$).

Next, the overall presence score (PSS) was calculated. Scores ranged from 3.35 to 6.05 ($M = 4.57$, $SD = .56$) on a seven-point Likert response format from "completely disagree" to "completely agree".

Finally, a principal component analysis was conducted on the 20 items, with oblique rotation (promax). Although we acknowledge the fact that the sample size is in principle not large enough to perform a factor analysis (Field, 2009), we still chose to perform it based on the KMO value and the values of the communalities. The Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis, KMO = .638. According to Field (2009), this is a mediocre but acceptable result. However, because not all KMO values for individual items exceeded the acceptable limit of .5 (Field, 2009), the same factor analysis was performed on a reduced number of items. Five items that had an individual KMO value below .5 were excluded. These items were: I succeeded to draw in indifferent ways, I paid attention to my musical instrument, I paid attention to the pressure mat, I paid attention to what happened around me, I paid attention to the screen, and I paid attention to the music.

After exclusion of these items, the Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis, KMO = .753. Individual KMO values were all above .5. Bartlett's test of sphericity X^2 (120) = 311.281, $p < .001$, indicated that correlations between items were sufficiently large for PCA. Communalities were rather high ($M = .685$, $SD = .12$).

An initial analysis was run to obtain Eigen values for each component in the data.

Five components had Eigen values over Kaiser's criterion of 1 and together explained 68.46% of the variance. Table 9.4 shows the factor loadings after rotation with an absolute value greater than 0.4.

The first component, accounting for 29.7% of the variance, consisted of items that measure the perceived quality of actions. These items expressed the degree of control, the immediacy and the mode of control, the perceptual non-mediation and the consistency of the actions with normal instrument playing. Their clustering suggests that this component is related to agency. The large percentage of the variance that is explained by this component points at the importance of the sense of agency.

The second component, accounting for 13.8 of the variance, clusters items related to cognitive load and to short and long term learning process required to interact with the system. This cluster therefore seems to represent learnability. The third component consisted of four items and accounted for 9.9% of the variance.

Items were related to the experience of the mapping of the system as natural, to the ability to predict the outcomes of one's actions, to the multimodal nature of the system and to the system's ability to stimulate creativity.

The fourth component, accounting for 8.1% of the variance, consisted of two items both related to used mechanisms, namely the musical instrument and the movement sensor.

The fifth and last withhold component also consisted of two items, namely the degree to which musical instrument and the movements captured the player's attention. This component accounted for 6.7% of the variance.

Table 9.4. Factor loadings (pattern matrix) for 15 items of the in-house designed presence questionnaire.

Pattern Matrix[a]	Component				
	1	2	3	4	5
Control	.853				
System Naturalness	.789				
Non-mediation	.788				
System Responsiveness	.460				
Unusual Actions (R)	.436				
Long Learning Phase (R)		.901			
Get Used (R)		.874			
Cognitive Load (R)		.628			
Natural Mapping			.894		
Anticipation			.676		
Multimodality			.550		
Creativity			.519		
Attention to sensor (R)				.883	
Attention to instrument (R)				.649	.406
Attention to movement (R)					.909

Principal Component Analysis with Promax rotation
loadings > .40
(R) = reversed item

Since both the fourth and the fifth component consisted of only two items, they are considered as rather weak and unstable components (Costello and Osborne, 2005; Velicer and Fava, 1998). This was also shown in the reliability analysis of the components. The first three components had reliability above the a cut-off value of .70, the fourth and fifth components had negative, and therefore nonsensical, values.

To summarize, the principle component analysis led to the extraction of three defining components, explaining 53.5% of the variance:

1. *Agency*: this first component is related to the way the musician perceives his or her own actions while interacting with the Music Paint Machine. Does it feel natural to use the system? Do the used mechanisms require attention? Were actions accompanied by a sense of control?
2. *Learnability*: this component is related to how quickly a musician feels competent to use the system. Does he or she need a long time to get used to the system? In other words, how fast can he or she learn to use the

Music Paint Machine in such a way that what he or she wants is what he or she actually gets.

3. *Interface Quality*: this component is related to characteristics of the medium. Does it react adequately to the musician's actions? Does it use a straightforward and naturally felt mapping from action to outcome?

However, next to these extracted components, the items that were excluded from the principle component analysis still have to be taken into account. Exclusion, based on their KMO value, indicates the impossibility of meaningfully clustering these variables into a component but makes no statement about their significance with regard to the overall scale, the PSS. A Spearman correlation test indicated that only one of these variables was significantly correlated with the PSS, namely varied drawing, $r_s = .424$, $p < .001$.

9.3.2.3. Presence and flow

To test for the relationship between flow and presence, several statistical methods were used.

First, analysis was performed on the two overall scores (FSS and PSS). Based on the definition of flow as a combination of the highest level of presence and a positive emotional condition (Riva, 2005), we hypothesized that a strong positive correlation exists between presence (independent variable) and flow (dependent variable). Since both presence and flow are always a matter of degree, it is expected that the higher the score for the presence state scale is, the higher the score for the Flow State Scale will be. After a Shapiro–Wilkinson normality test, a bivariate correlation analysis (Pearson's r) was run on the scores for the flow and presence state scales. A strong correlation, $r = .598$, $p < .001$, between both variables was found.

Second, after the inspection of the corresponding scatter plot, a simple linear regression was performed to further assess the relationship between both scales and to test the hypothesis that presence predicts flow. The Presence State Scale significantly predicted the Flow State Scale, ($b = .805$, $t(61) = 5.823$, $p < .001$) and explained a significant proportion of variance in the Flow State Scale, ($R^2 = .357$, $F(1, 61) = 33.9$, $p < .001$).

Third, a multiple linear regression analysis was performed on the extracted presence components (Agency, Learnability, Interface Quality) and the FSS. The results of the regression indicated the three predictors explained 61.3% of the variance ($R^2 = .631$, $F(3, 61) = 34.79$, $p < .001$). It was found that Agency significantly predicted the FSS ($b = .60$, $p < .001$), as did Interface Quality ($b = .314$,

$p < .001$). The Learnability component did not have a significant predictive value ($b = .069$, $p = .443$).

Fourth, to determine the nature of the relationship between the underlying structures of both the constructs of flow and presence, a canonical correlation analysis was performed between the extracted presence components and the flow dimensions.

Tests of dimensionality for the canonical correlation analysis, as shown in Table 9.5, indicate that one of the three canonical dimensions is statistically significant at the .001 level. This dimension had a canonical correlation of 0.913 between the sets of variables.

Table 9.5. Tests of Canonical Dimensions.

Dimension	Canonical Correlation	Mult. F	df1	df2	p
1	.91352	6.06	27	52.00	**.000**
2	.53033	1.37	16	102.00	.170
3	.24158	.46	7	52.00	.859

Table 9.6 presents the standardized canonical coefficients and the correlations between (1) the dependent variables (flow) and covariates (presence) and (2) the canonical variables.

For the flow dimensions, the extracted canonical dimension is most strongly correlated with the dimension Merging of action and awareness (-.92) and the dimension Sense of control (-.95). With regard to the presence components, Agency (-.92) and Interface Quality (-.60), were the dominating variables for the extracted canonical dimension.

Fifth, a correlation analysis (Spearman's *r*) was performed between the flow variables and the presence items (varied drawing, attention to screen, attention to music, attention to mat, attention to surroundings) that did not cluster and therefore were excluded from the principle component analysis. The strongest correlation was found between the fact that a participant paid attention to the screen and was focused on the task at hand, $r_s = .518$, $p < .001$. Participants' paying attention to the music significantly correlated with the fact whether they experienced a balance between skill and challenge, $r_s = .438$, $p < .001$. Attending to the music was also significantly correlated with having an autotelic experience, $r_s = .355$, $p < .001$. Furthermore, believing to have succeeded in drawing something in different ways was significantly correlated with having an autotelic experience, $r_s = .333$, $p < .001$. This was also the only item that correlated significantly, at the .001 level with the FSS, $r_s = .328$.

Table 9.6. Correlations between the dependent (flow)/covariates (presence) and the canonical variables.

		canonical dimension 1	standardized r_c
Flow Dimensions	Challenge/skill balance	-.44732	.07883
	Clear goals	-.57274	-.03371
	Unambiguous and immediate feedback	-.70822	-.18244
	Merging of action and awareness	**-.92771**	**-.36893**
	Concentration on the task at hand	-.10894	.04617
	Sense of control	**-.95060**	**-.52132**
	Altered time perception	-.33002	.04646
	Loss of self-consciousness	-.10984	-.02488
	Autotelic experience	-.58284	-.11417
Presence Components	Agency	**-.92499**	**-.83293**
	Learnability	-.42286	.01627
	Interface Quality	**-.60221**	**-.39259**

Noteworthy to mention, in view of a detailed account of the relationship between aspects of presence and flow are the correlations between the FSS and the naturalness of using the system, $r_s = .721$, $p < .001$, and between the FSS and the perceptual non- mediation, $r_s = .650$, $p < .001$.

9.3.3. Discussion of the results

The present study aimed at probing the subjective experience of the participants and examined the relationship between flow and presence in the context of interactive music systems. In what follows we discuss the limitations of our in-house designed presence questionnaire (9.3.4.1), on how are findings are related to the original questionnaire (9.3.4.2), on the found relationship between flow and presence (9.3.4.3), on the use of the constructs of flow and presence in the context of interactive music systems (9.3.4.4) and on how presence and flow relate to embodiment (9.3.4.5).

9.3.3.1. The presence state scale questionnaire

While the Flow State Scale questionnaire was found suitable in the context of interactive music systems, we found no presence questionnaire that could be used in this particular context. Therefore we designed our own questionnaire, based on the theoretical elaborations of presence and starting from items of the PQ (Witmer and Singer, 1998; Witmer et al., 2005). Although many of the findings suggest consistency with theoretical assumptions, the reliability of this questionnaire (α = .64) could be improved. Further development and optimization of the questionnaire is challenging but we believe it might contribute to the further elaboration of a user-oriented approach in the field of embodied music cognition (see also: Leman et al., 2010). Items in this questionnaire that were based on the PQ items must be partially revised, mostly concerning the sensory factors. Furthermore, increasing the sample size with corrections with regard to the distribution of for example age, skill level and musical background and further analysis of the dataset (e.g. investigate the relationship between presence and musical background or background in computer use, the role of skill or level of experience) are needed. Based on the results of the canonical correlation, it might be argued that a possible way to proceed could be to integrate both questionnaires (FSS and PSS) into one questionnaire.

9.3.3.2. Relationship of current findings on Presence to previous findings with the PQ

Despite the fact that a further elaboration and refinement of our presence questionnaire is required, the extraction of the three components related to agency, learnability and interface quality seems to resonate with previous research. First, the extraction of a component related to agency is in line with the theoretical elaboration of presence as a moment-by-moment self-monitoring process that informs a person whether actions are performed in accordance with his or her intentions and goals (Riva, 2008; Riva et al., 2009). In line with Witmer et al. (2005), this first component is a combination of previous revealed separate subscales (Witmer and Singer, 1998), namely Involved/Control and Natural.

Second, the Learnability component relates to presence conceived of as a mechanism that informs about the relationship between goals and results. Learnability is acknowledged as important to the establishment of action perception couplings (see Zahorik and Jenison, 1998). It is also acknowledged as an important factor for the interaction with a computer system (Vertegaal et al., 1996).

Third, the component related to interface quality is a factor that has been found in previous research (Witmer et al., 2005; Witmer and Singer, 1998). However, in contrast to Witmer and Singer’s Interface Quality subscale, this component was not so much related to attention. Here items were rather about how the system responsiveness was experienced, how consistent or natural the system’s mappings were, and how much metal effort the system required.

Remarkably, four out of the five items that were excluded from the principle component analysis, namely attention to screen, attention to music, attention to mat, and attention to surroundings, were related to the original Sensory Factors (Witmer and Singer, 1998) and to the Sensor Fidelity Factor (Witmer et al., 2005). None of these items were significantly correlated with the PSS. This means that with regard to the questionnaire design, questions have to be revised to better capture the sensory aspect of presence. The fifth excluded factor, I succeeded to draw in different ways, was positively correlated with the PSS. This item might be related to the feeling of successfully enacting one's intentions.

9.3.3.3. Flow and presence

Findings from this study seem to empirically validate the theoretically elaborated relationship between the constructs of flow and presence. Results from the statistical analysis suggest a strong relationship between both constructs and confirmed our hypothesis that presence has a predictive value for flow. These results are in line with previous findings on presence as a flow facilitator (Novak et al., 2000; Park and Hwang, 2009). The followed statistical path aimed at scrutinizing the nature of this relationship. After having ascertained the relationship between the overall scales, namely the FSS and the PSS, further analysis aimed at determining how the underlying structures of both constructs are related to each other.

Correlation analysis (Pearson r) revealed that the presence state scale was strongly correlated with the flow dimensions merging of action and awareness and sense of control. This result was mirrored in the fact that canonical correlation analysis clustered the flow components *merging of action and awareness* and *sense of control* with the presence components *agency* and *interface quality* into a canonical variable. This suggests that (1) the feeling of being in control, (2) the fact that the system accommodates this feeling through its responsiveness and its naturalness and (3) the fact that using this system allows for action and awareness to emerge, are the underlying aspects of the intrinsic relationship between flow and presence. These results are in line with theoretical elaborations on the relationship between flow and presence in which the importance of control/agency and involvement is emphasized (e.g. Jacobson, 2001, 2002; Riva, 2009). Moreover, they can be related to the conceptions of presence as the "feeling of being there" (e.g. Ijsselsteijn and Riva, 2003) and as the "perceptual illusion of non-mediation" (Lombard and Ditton, 1997). When action and awareness merge, a person is acting proximally ("here") but thinking distally ("there") (e.g. Loomis, 1992; Polanyi, 1966). Additionally, while being totally focused on the results of one's actions, stimuli related to the actions needed to produce these results disappear from consciousness. This is only possible when the system responds well and using it feels natural. When this is the case, it invokes the so called "perceptual illusion of non-mediation", i.e. when mediating artefacts of an activity disappear from consciousness and allow to completely focus on the task at hand (e.g. Nijs et al., 2009). This aspect is supported by the strong correlation that was found between the presence items non-mediation and system naturalness with the FSS. Furthermore, the system's responsiveness and naturalness also enables its user to perceive oneself to be the agent in control (e.g. Mulder, 2000; Nosulenko et al., 2005).

The fact that the Learnability component had no significant predictive value for flow seems to confirm the findings of Turner (2008) who found in a study on familiarity with interactive devices that it is not the learnability with the technology per se that is the most important factor but rather the actual consequences and focus of the learning.

Remarkably, none of the three components of presence correlated with the flow dimension "focused on the task at hand". In view of the generally acknowledged important role of attention processes in presence, this is a notable result. It might be explained by the explorative nature of the experiment: no concrete guidelines were given and participants had to concretize the task on their own initiative and inventiveness to make a digital painting. Many participants explored the possibilities of the system without defining for themselves a concrete drawing task (e.g. draw geometric figures or concrete objects such as for example a house or boat). Taken into account that most of the participants had no experience in improvising, this explorative behaviour is in line with the improvisation skills model as proposed by Kratus (1991). In this model, exploration is the first of seven levels that mark out a learning curve in the development of improvisation skills. Further experiments are needed to see the effect of very concrete tasks and how these affect attention processes when interacting with the Music Paint Machine. An aspect that did correlate with the flow dimension "focused on the task at hand" was the fact whether one's was paying attention to the screen or not. This finding seems logical, considering the fact that the task involved to create something "on the screen".

The findings above suggest the importance of the so-called illusion of non-mediation for flow. In the literature on flow, this aspect seems underrepresented. And yet this perceived non-mediation – and accordingly the degree to which the system is experienced as an extension of the body (Nijs et al., 2009, in press) – is very important for the possibility to focus on the task (Loomis, 1992; Polanyi, 1967; Finneran and Zhang, 2003). Therefore we believe that the construct of flow can be elaborated upon in depth by integrating the construct of presence. Further research is needed to empirically investigate the role of the different layers of presence (Riva et al., 2004a,b).

9.3.3.4. Presence and flow in the context of interactive music systems: the case of the Music Paint Machine

In this study, first steps were undertaken to introduce the measurement of presence in the domain of interactive music systems and related research. Based on a theoretical investigation of the musician–instrument relationship (Nijs et al., 2009, in press), it was found that presence is a viable construct in order to elaborate on the interactive processes during music performance. Therefore it was assumed that measuring presence is an appropriate method to, first, examine whether and, if so, to what extend the Music Paint Machine creates a meaningful environment for the musician and, second, to probe the possible immersion in this environment. This information is vital for the development of the system into an optimal learning tool. Especially when presence is closely related to flow. After all, the goal of the Music Paint Machine is to provide musicians with a flow-like experience in order to stimulate creativity, enhance the relationship with the instrument and develop an embodied understanding of the music.

The presented results suggest such a close relationship between flow and presence.

This implies that soft- and hardware adaptations that optimize the system in function of presence, will also positively affect its flow potential. According to Riva et al. (2004a,b), the technical demands of eliciting presence are less the higher the layer invoked. But designing a system that has the potential to elicit an optimal presence experience needs to enable the integration of the three layers of presence. The authors argue in favour of three design routes that can stimulate the sense of presence. The first route, digital participation, refers to the emotional and intellectual engagement. In the domain of virtual reality this means that the user of the system is the agent in an interactive drama. The second route, mediated flow, is related to perceived control and focus on the interaction, to the arousal of curiosity and to interest in the interaction. The third route, embodied immersion, is related to the style of the interaction, namely to the integration of bodily movements as direct inputs from the user. We believe that these three design routes are applicable within the domain of interactive music systems. These systems, especially when movement based, are capable of evoking digital participation, mediated flow and embodied immersion. Measuring the sense of presence when engaging with such systems might therefore capture essential aspects of the interaction, related to the role of the body as the natural mediator of human experience.

9.3.3.5. Presence, flow and embodiment

The empirically observed correlation between flow and presence can be understood from the viewpoint of embodied music cognition. We believe that embodiment is an interesting concept for understanding the mechanism that may connect the concepts of flow and presence. We argue that this underlying mechanism is the action-perception principle. Results of the empirical study seem to support this line of thought.

From the viewpoint of embodiment, the body mediates human experience by establishing a link between the environment and the experience. This link is based on the coupling of action and perception, which constitutes the mutuality between subject and environment. In this way action perception couplings provide access to the environment (perception) and enable a corporeal attunement with the environment that facilitates an embodied interaction (action).

It can be argued that the coupling between action and perception is a mechanism that underlies the intrinsic relationship between flow and presence.

First, the coupling of action and perception is crucial for determining the extent to which a subject has access to the environment and actions are successfully supported by it (Zahorik and Jenison, 1998). As such, this mechanism is a common ground for both conceptualizations of the quality of human experience. It underlies different flow dimensions such as the balance between skills and challenge, immediate feedback, sense of control and merging of action and awareness. It also underlies presence as the monitoring mechanism that informs a subject on the possible successful enaction of his intentions. This is reflected in the extraction of a presence component related to agency.

Second, the coupling of action and perception is the mechanism that allows for a presence-based elaboration of the role of the body and, particularly, its extensions for flow. If flow, as the results of our study suggest, involves optimal presence, then it is only possible when proto presence is achieved. Proto presence only occurs when it is possible to correctly couple perceptions and movements (action) and to use the body to successfully enact intentions. This implies that the "correct" coupling of action and perception is characteristic for an optimal sense of presence and vital for flow. In other words, it is through the action perception couplings that the body mediates experiences and its perceived quality.

Accordingly, when engaging with an interactive music system such as the Music Paint Machine, the quality of the musician's experience is determined by the quality of the bodily engagement as reflected in the degree to which action and perception match. Therefore the system must be designed in such a way that the material components (e.g. motion sensor, pressure sensing mat, screen) and the actions that are required to use the system do not hinder a direct and engaged – bodily – participation (embodied interaction) in the environment that is created by using the system. The musician must be able to act in accordance with his skills (skill-based playing). Here the degree to which the musician feels in control, the naturalness of using the system, the degree to which unusual action are required and the degree to which system mechanism capture attention are important elements that influence the musicians interaction with the system. When these elements are favourable, the musician will feel competent in using the system. Additionally, the system must be designed in such a way that it does not hinder perception. The musician must be able to effortlessly pick-up the necessary information (direct perception) to evaluate a possible match between intended an actual results (e.g. what happens on the screen). Here the nature of the mapping and the degree to which the system allows to anticipate the results of an action are of importance.

When a system allows skill-based playing (e.g. painting with sound and movement) and direct perception (e.g. what happens on the screen), it does not interfere with the mediating role of the body for the musician's experience. The system can become transparent in use and can be experienced as a natural extension of the musician that, unified with the body, mediates the access to the created environment.

The importance of the action perception coupling principle – and thus the role of the body and its extensions – for the aforementioned characteristics of the system and their impact on the musician's experience are reflected in the clustering of the items relating to these characteristics into the agency and interface quality components. Through the clustering of these components with the flow dimensions related to control (sense of control) and to the immersion in the activity (merging of action and awareness), results of the empirical study with the Music Paint Machine shed light on how measuring presence might reveal the role of the body for flow.

9.4. Conclusion

In this paper we presented an approach to the measurement of the subjective experience of musicians engaging with an interactive music system, the Music Paint Machine. This system allows a musician to create a digital painting by playing an acoustical music instrument and moving on a pressure sensing mat. The design of this interactive system is embedded in an embodied cognition approach to musical experience, in which interactive music systems are conceived as extensions of the human body. As such they have a major impact on the role of the body as the natural mediator of human experience.

To examine the nature of an experience with the Music Paint Machine, we used the constructs of flow and presence. Flow experience was measured with the Flow State Scale, presence with an in-house designed questionnaire. Based on theoretical accounts of the relationship between both constructs, we hypothesized that presence has a predictive value for flow. Statistical analysis confirmed this hypothesis. Furthermore, findings suggest that the intrinsic relationship between flow and presence is related to agency or control, interface quality and the merging of action and awareness.

Despite the explorative nature of the experiment and, consequently, the preliminary nature of the findings, results seem to resonate theoretical elaborations. However, findings also pointed to the need to further elaborate and refine the in-house designed questionnaire, especially with regard to the sensory aspects of presence. Further experiments are needed to test the reliability and validity of a next version of the questionnaire. A possible way to proceed might be to integrate flow and presence into one questionnaire. Furthermore the methodology of the experiments must be elaborated. Especially different tasks and variations of the system can be used to conduct more controlled experiments.

We believe for several reasons that music provides an excellent research domain in which presence can be studied. First, interactive music systems become more and more important in the cultural creative sector (e.g. music performance, education). The development and implementation of these systems demand for a user-oriented approach that has a strong theoretical ground. This ground can be provided by elaborating on flow and presence within the embodied music cognition paradigm.

Second, interactive music systems are often movement based. Using the construct of flow and presence in empirical studies with these systems might therefore reveal interesting aspects on the role of the body for the quality of subjective experience while engaging with such a system. Again, presence research and the embodied music cognition research paradigm might join and establish a firm empirical framework.

Third, bringing the construct of presence in the domain of interactive music systems might broaden the use of presence towards research on artistic expression and creativity. Finally, interactive music systems often use sensing technologies that provide objective data on, for example, movement and sound. This enables the combination of objective and subjective measurement of presence. Moreover, these systems are always multimodal. Therefore experiments with such systems can contribute to research on cross-modality and how the precise coupling of different modalities affects presence.

CHAPTER 10

The influence of a multimodal interactive educational technology on the developmental music aptitude: A longitudinal case study with the Music Paint Machine

NIJS, L., LESAFFRE, M. & LEMAN, M. The influence of a multimodal interactive educational technology on the developmental music aptitude: A longitudinal case study with the Music Paint Machine. Submitted to *Music Education Research*.

Abstract

In this paper we describe a nine-month longitudinal study in which twelve children (1st and 2nd grade) learned to play the clarineo. Six of the children received instruction with an interactive music system, called the Music Paint Machine. This educational technology allows a musician to make a digital painting by playing music and by moving on a coloured pressure mat. The overall goal of this study was to develop good practices with the Music Paint Machine, on the basis of which the effectiveness of instruction with the system could be evaluated. To measure the effectiveness, children were administered the *Primary* and *Intermediate Measures of Music Audiation* (Gordon, 1986). It was hypothesized that using the Music Paint Machine during instruction would contribute to the development of tonal and rhythmic discrimination skills and, as such, to the developmental tonal and rhythmic aptitude. To test the hypothesis, a non-equivalent control groups design was used. The results of this study did not reveal a significant difference between the control group and the treatment group. However, in this study it became clear that conducting research with an educational technology in an ecological setting demands for measurement methods that go beyond a product oriented approach in which a pre-test post-test design is used to test the effectiveness (amplicative impact) of the technology.

10.1. Introduction

In this paper we describe a nine-month longitudinal study in which twelve children learned to play the clarineo, six of which received instruction with an interactive music system, called the Music Paint Machine. This educational technology allows a musician to make a digital painting by playing music while moving on a coloured pressure mat (Nijs, Moens, Lesaffre, & Leman, 2012).

This study is part of an experimental trajectory that aims at developing an educational technology for instrumental music instruction (Nijs, et al., 2012).

The overall goal of this study was to develop good practices with the Music Paint Machine and to verify the effectiveness of instrumental instruction with the system based on these practices. To measure the effectiveness of the technology-supported instruction, we use the *Primary* and *Intermediate Measures of Music Audiation* (Gordon, 1986). According to Gordon (1986, 2007),

- *music aptitude does not stabilize until the age of nine*
- *a child's music aptitude can change depending on the quality of the music instruction it receives*
- *the importance of quality in classroom formal music instruction can not be overestimated*

In this study, it was assumed that learning how to play a musical instrument with a multimodal educational technology such as the Music Paint Machine would contribute to the quality of instruction. Previous research results have suggested that the Music Paint Machine has the potential to induce an optimal experience while engaging in an interactive loop with movements, music and visual output (Nijs, et al., 2012). As such it can profoundly influence the quality of the children's learning experience (Csikszentmihalyi, 1997; Shernoff & Csikszentmihalyi, 2009; Shernoff, et al., 2003; J. Webster, Trevino, & Ryan, 1993). Furthermore, amateur musicians and teachers positively evaluated the didactic potential of the system (Nijs, et al., 2012).

It was also assumed that the Music Paint Machine would contribute to the components of musical ability, based on its specific use of visual feedback (e.g. on pitch, note duration) and on its potential to stimulate playfulness with musical parameters. According to Schmidt (2006) the components of musical ability are:

- *basic mental operations* (e.g. auditory sensation, attention, perception, encoding in working memory)
- *musical knowledge and performance skills* (e.g. cognitive musical information and psychomotor skills derived from training)
- *problem-solving ability* (e.g. make use of available information, rapidly adjust incoming information*).*

One of the features of the Music Paint Machine is that the visual feedback can clearly represent whether melodic or rhythmic patterns are the same or different. Figure 10.1a. shows how a melodic pattern (e-g) is visually represented on the screen. Figure 10.1b shows how patterns can be compared by overwriting one another on the screen. Figure 10.1c shows how the screen can be split to compare the patterns that are played by, for example, two different children. In this way the visual feedback can complement the auditory discrimination of pitch.

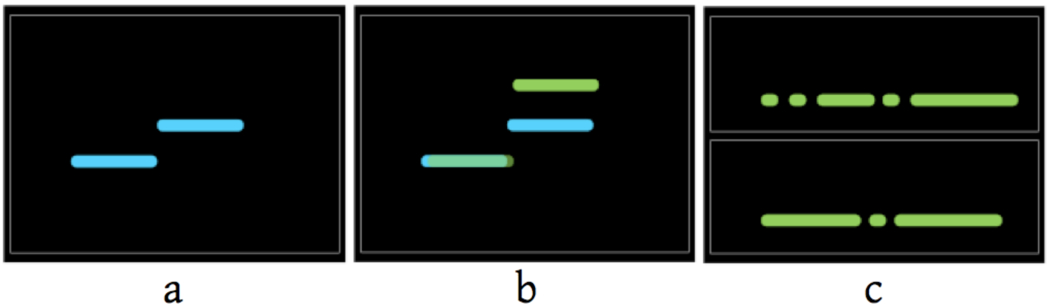


Figure 10.1. The "painting" of the Music Paint Machine gives additional visual feedback on pitch differences (a). In this example pitch is mapped to position on the vertical axis, while duration is mapped to length on the horizontal axis. Children can try to overwrite (b) or copy (c) tonal or rhythmic patterns.

Based on these assumptions and on the specific features of the system, it was hypothesized that using the Music Paint Machine to support instrumental music instruction would positively contribute to the development of tonal and rhythmic discrimination skills and, as such, to the development of tonal and rhythmic aptitude.

The effect of visual feedback has been studied mainly with regard to pitch-matching or pitch-control (singing in tune), especially in the context of accurate singing (e.g. Wilson, et al., 2008). In addition, studies have also shown that pitch-matching skills are not necessarily correlated with pitch discrimination skills

(Moore, Estis, Gordon-Hickey, & Watts, 2008; Morrison & Fyk, 2002; Tsang, Friendly, & Trainor, 2011). However, we found no studies in which pitch discrimination was investigated with regard to the possible effect of visual feedback.

Several studies in the domain of instrumental music instruction have used Gordon’s measures of music audiation (Gordon, 1986). For example, Flohr (1981) conducted a study with five year old children who received different kinds of instruction (instrumental improvisation vs. sing, play and move) or no instruction at all. Results indicated that short-term music instruction influenced the children's developmental music aptitude. Schlaug and colleagues (2005) studied the effects of music training on children’s brain and cognitive development. They concluded that one year of instrumental music instruction lead to significantly better scores (compared to the control group) with regard to auditory discrimination skills, as measured by Gordon’s Primary Measures of Music Audiation (PMMA). Forgeard and colleagues (2008) conducted a study to investigate whether instrumental music training in childhood is associated to outcomes closely related to music training. Children who received three years or more of instrumental music training outperformed their control counterparts on auditory discrimination abilities. It was also found that the duration of training predicted the outcomes. In a study to verify whether the traditional large group singing instruction versus a small-group/individual singing instruction has an effect on development music aptitude, Rutkowsky (1996) did not find significant differences on the PMMA scores of both the control and experimental group. Tai (2010) examined the effect of violin, keyboard, and singing instruction on four to seven year old children’s musical aptitude. Results showed a significant difference among the three instructional groups with regard to tonal aptitude. The singing group’s tonal aptitude scores had a statistically significant increase, while the scores of violin and keyboard groups remained statistically constant over time.

In this study we used the Primary and Intermediate Measures of Music Audiation to test the hypothesis that instruction with the Music Paint Machine positively contributes to the development of music aptitude. We are not aware of other studies that test the effectiveness of educational technologies, using Gordon’s Measures of Music Audiation.

This paper is organized as follows: first we describe the method of this study, followed by a section on the data analysis and the results and, finally, the discussion and conclusion.

10.2. Method

10.2.1. Participants

In this study, twelve children (first and second grade, six boys and six girls) and one teacher (the researcher in this study and first author of this paper) participated. Seven children were grade one and five children were grade two. Most of the children's parents were highly educated. Twenty-one percent of the parents hold a PhD and thirty-eight percent holds a master or equivalent diploma. Only twenty-five percent of the parents played a musical instrument themselves.

The researcher-teacher received formal training in music performance and music teaching. He was a clarinet, saxophone and ensemble teacher for fourteen years.

10.2.2 Design

This study was *exploratory* on different levels, namely on the level of measures, methodology and didactic practices:

- *Measures*: We used an in house designed questionnaire on the participants' home musical environment (see Appendix B). This questionnaire needs to be further developed and tested on its reliability and validity. The Schwarzer self-regulation scale and the Movement Assessment Battery for children 2 (M-ABC2) are rarely used in the context of instrumental music education.

- *Methodology:* This study aimed at the development of a methodology for a pedagogically grounded experimental framework that allows investigating musical learning processes in a naturalistic classroom setting. Methods were explored that enable to cope with the complexity of a naturalistic classroom setting. Refining the methodology by allowing this complexity and by learning to cope with it, is crucial to make the experimental trajectory converge into an application that fully realizes its didactic potential as theoretically argued.

- *Didactic practices:* During the lessons, different uses of the Music Paint Machine were explored and tested. Adequate use of the system had to be developed throughout the study.

This study was a *longitudinal case study*. The experiment ran during a period of nine months, involving the repeated measurement of the dependent variables for each participant. It is a case study because participants received instrumental music instruction with the support of a particular educational technology, namely the Music Paint Machine.

The experiment had *a non-equivalent control groups design*. It used a pre-test and post-test to measure the effect of the treatment (see Table 10.1).

Table 10.1. Diagram of the experimental design of the study. Groups were non-equivalent (N). The study used four measurements (O) of music aptitude as dependent variable. In between the measurements, children received instrumental music instruction. The treatment group received instruction with the Music Paint Machine (X).

N	O	X	O	X	O	X	O
N	O		O		O		O

Due to organizational constraints and small sample size, random assignment to a group was not possible. Because the children sometimes could not come to the lesson at a time set by the researcher, a timetable was constructed to schedule the lessons of the children in such a way that the parents' demands were met but at the same time age and grade of the children were as equally as possible distributed (see Table 10.2).

Table 10.2. Assignment of the children to the control or treatment group aimed at an equal distribution with regard to age and gender.

	AGE	GRADE	GENDER
Control Group A	7	2	m
	6	1	f
	7	2	f
Control Group B	6	1	m
	6	2	m
	6	1	f
Treatment Group C	6	1	m
	5	1	m
	7	2	f
Treatment Group D	7	2	f
	6	1	f
	5	1	m

Control Groups			
Gender	#	Grade	#
m	3	1	3
f	3	2	3

Treatment Groups			
Gender	#	Grade	#
m	3	1	4
f	3	2	2

To cope with the *selection threat*, a profile of each child was built up on the basis of different pre-tests (Raulin & Graziano, 1994). Using the profiles, possible confounding variables (e.g. home musical environment, personality) were mapped and could be taken into account when comparing results of the post-tests. Furthermore, measuring the between-subjects differences before exposure to the intervention, namely instruction with the Music Paint Machine, could substantially reduce the selection threat.

In this study, a combined *within and between subjects design* was enabled by repeatedly measuring the same variables over the whole period. Some variables were measured weekly (e.g. home study, classroom experience); music aptitude was measured every three months.

Finally, a *concurrent mixed method* design was employed. Data were collected using both quantitative (e.g. music aptitude test) and qualitative (e.g. questionnaires) measurement methods.

Tabel 10.3 summarizes the design of this study.

Table 10.3. Summary of the design.

exploratory	measures didactic practices methodology
longitudinal	nine months
a case study	the case of the Music Paint Machine
non-equivalent control groups	pre-test / post-test no random group assignment
within and between subjects	
concurrent mixed method	standardized tests questionnaires

10.2.3. Apparatus

10.2.3.1 Classroom

For this project, a studio-like classroom was constructed at our research institute, using a hexagonal iron framework that was closed with curtains (see Figure 10.2). The framework allowed attaching a beamer, a microphone and two cameras in a minimal obtrusive way.

Figure 10.2. The classroom that was setup for the study.

10.2.3.2 The Music Paint Machine

The Music Paint Machine has been described in detail in chapter 5. Here we present a short overview of the system (see Figure 10.3).

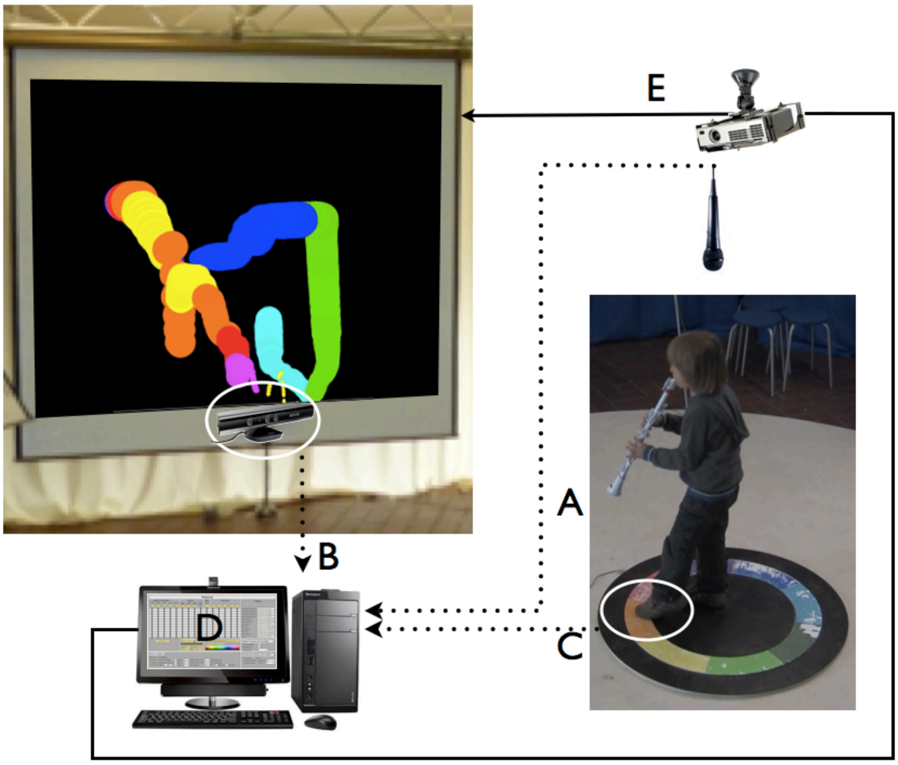


Figure 10.3. Overview of the Music Paint Machine. The child's sound (A) and movements are tracked with a Kinect® motion sensor (B) and a coloured pressure sensing mat (C). Movements and sound are then analyzed and computed via the system's software (D) and projected on the screen with a beamer (E).

The core of the system is the software that allows the dynamic mapping of movement and sound to a visual representation, the "painting". According to the content of instruction, the mappings can be altered. Furthermore the system can be aligned with the skills of the player (e.g. range of loudness and pitch).

The hardware of the system currently entails a computer, a beamer, a Kinect® camera, a microphone and an in-house designed mat with a pressure sensing colour wheel.

10.2.4. Materials

Prior to the instruction, the parents and the children participated in a number of pre-tests. Parents were administered three questionnaires in which they could report on their child's self-regulation skills, home musical environment and personality. The children participated in two pre-tests. One test probed the children's music aptitude; the other tested the children's motor skills.

Throughout the study, parents completed a form on home study (integrated in the children's diary) on a daily basis. The children were administered a short questionnaire on classroom experience after each lesson. In the next sections we describe the materials in more detail. In Table 10.4 we present an overview of the materials.

Table 10.4. Overview of the materials used in this study. ST = standardized test, Q = questionnaire.

	Children	Parents
pre-tests	◦ Movement Assessment Battery for children (ST) ◦ Primary Measures of Music Audiation (ST)	◦ Self-regulation skills (Q) ◦ Home musical environment (Q) ◦ Personality (Q)
in between tests	◦ Primary or Intermediate Measures of Music audiation (ST) ◦ classroom experience (Q)	◦ Home study (time/day) (Q) ◦ Parental support (Q)
post-test	◦ Primary or Intermediate Measures of Music audiation (ST)	

10.2.4.1 Questionnaires

In this study two sets of questionnaires were used. A first set was used to make a profile of the children and probed self-regulation skills (SSRS), home musical environment (HME) and personality (H*i*PIC). A second set was used to probe aspects of the learning process: classroom experience (CEQ) and home study (HS).

Schwarzer Self-regulation scale (SSRS)

Learning how to play a musical instrument is a difficult and intensive task that requires a great deal of self-regulation, i.e. the ability to organise one's own learning (Bransford, 2000; McPherson & Zimmerman, 2002). This is especially the case in the initial stages when young learners have to overcome a lot of difficulties that may lead to confusion and failure and thereby may challenge motivation. Therefore self-regulation has to be taken into account as a variable that might influence the children's behaviour and learning experience.

The questionnaire on self-regulation that was used in this study is the Schwarzer Self-regulation Scale (Schwarzer, Diehl, & Schmitz, 1999). This scale refers to the post-intentional self-regulation when individuals are pursuing a goal and face difficulties in maintaining their action. In such a maintenance situation it is required to focus attention on the task at hand and to keep a favourable emotional balance. The original questions were translated into Dutch and formulated from the viewpoint of the parent ("My child" in stead of "I"). The response format of the questionnaire is as follows: (1) not at all true, (2) barely true, (3) moderately true, (4) exactly true.

Home Musical Environment (HME)

The degree to which music plays a role in the daily environment of children has been acknowledged as an important factor that influences children's musical development in general (Gembris & Davidson, 2002; McPherson, 2006, 2009) and music aptitude in particular (Gordon, 2007). When children start music lessons they do not arrive as an empty vessel that needs to be filled with musical experiences. On the contrary, they bring with them a myriad of musical experiences that undoubtedly shape and influence their musical learning process. To understand how their learning process evolved and to what degree their musical development might have been influenced by the role music plays in their lives outside the classroom, it was important to learn about the children's home musical environment, i.e. the musical activities a child engages in within a family context.

In this study we used an in-house designed questionnaire. Items were related to the musical background and the musical activities (playing, singing, dancing, listening) of the parents, the participating children and their siblings (see Appendix B).

Personality (HiPIC)

Several studies have indicated that personality affects the way people learn, showing a relationship between personality and aspects of learning such as motivation (Klein & Lee, 2006; Komarraju, Karau, & Schmeck, 2009), self-regulation (Fein & Klein, 2011), learning styles (Komarraju, Karau, Schmeck, & Avdic, 2011) and academic achievement (e.g. Diseth, 2003). In music related research, personality has mostly been linked to musical preferences (e.g. Chamorro-Premuzic & Furnham, 2007; Rentfrow & Gosling, 2003), to performance anxiety (e.g. Rae & McCambridge, 2004) and, in the domain of education, to effective music teaching (Teachout, 2001). Schmidt (2006) developed a model of musical ability that integrates aspects of personality.

Taking into account the relationship between personality and learning, assessing the participating children's personality seemed a necessary part of mapping the potential confounding variables of this study. We used the Hierarchical Personality Inventory for Children or H*i*PIC (Mervielde & De Fruyt, 1999). This questionnaire was developed to assess traits of children aged six to twelve years. It has five domain scales: extraversion, benevolence, conscientiousness, emotional stability, and imagination.

These labels reflect the characteristic behaviour of children in the eyes of their parents, who are most often used as primary informants of children's traits. Items were rated on a five-point Likert scale ranging from *uncharacteristic* (1) to *very characteristic* (5). Table 10.5 shows the five domains of personality and their facets.

Table 10.5. The five domains of personality and their different facets according to the Hierarchical Personality Inventory for Children (H*i*PIC).

EMOTIONAL STABILITY	EXTRAVERSION	IMAGINATION	BENEVOLENCE	CONSCIENTIOUSNESS
Anxiety	Energy	Creativity	Altruism	Concentration
Self-confidence	Expressiveness	Intellect	Dominance	Perseverance
	Optimism	Curiosity	Egocentrism	Order
	Shyness		Compliance	Achievement
			Irritability	Striving

Classroom Experience Questionnaire (CEQ)

The classroom experience of the children emerges from the activities they participate in during a lesson. The way children perceive these activities and their role within them influences their engagement and accordingly their achievement (Reyes, Brackett, Rivers, White, & Salovey, 2012; Shernoff & Csikszentmihalyi, 2009).

To assess how children experienced each lesson, a short questionnaire was administered at the end each lesson. Children expressed the degree to which they agreed or disagreed with five statements, using a smiley face four point Likert scale with an "I don't know" option added (see Figure 10.4). The use of pictorial Likert scales has been acknowledged as a viable and reliable way to use questionnaires with young children (e.g. Reynolds-Keefer & Johnson). To avoid the children being affected by the picture, a rather neutral representation of the faces was used.

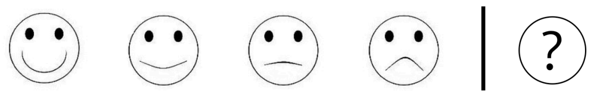


Figure 10.4. The pictorial likert scale that was used in the Classroom Experience Questionnaire.

Questions were related to (1) whether they experienced the lesson as fun (enjoyable), (2) whether they learned something (instructionable), (3) whether they understood the instructions (understandable), (4) whether they experienced the lesson content as being difficult (difficult) and (5) whether they felt they did well (successful). Initially the teacher assisted the children by asking the questions aloud and by completing the questionnaire. Gradually students became acquainted with it and several students completed the questionnaire themselves.

The authors were aware of the possible occurrence of the *recency effect*, in the sense that what happened at the end of the lesson might have affected the children's response to the questions. However, while this may seem a threat to the reliability of the data, this is not necessarily the case. Due to the same recency effect, their perception of the lesson as expressed in their responses to the questions of the CEQ is probably also what they take home and, accordingly, what will influence their opinion about the lesson.

Student diary: home study and parental support

Practice time is an element that plays an important role in the learning process of a beginning instrument player (e.g. Hallam, 2004; Sloboda, Davidson, Howe, & Moore, 1996). Moreover, the way parents are engaged with the subject matter and support practicing has been found to positively affect children's musical learning (e.g. Creech, 2010; Macmillan, 2004; McPherson, 2009; McPherson & Davidson, 2002).

In this study we used a simple diary in which home tasks and points of attention for practice were specified after each lesson. This diary contained a section on practice time and parental support (see Appendix C). Parents were asked to complete this section on a daily basis by writing down how much time their child spent on practice. Additionally, parents were asked to indicate whether and, if so, by whom practicing was supported.

The authors are well aware that the data from this questionnaire might not provide an exact measurement of practice time. After all, sometimes parents may have forgotten to complete the form or they may have guessed the amount of time their child practiced. However, we believe that the results may give an indication of the parental support and the efforts of the student at home.

10.2.4.2 Standardized Tests

Movement Assessment Battery for Children (M-ABC2)

Learning how to play a musical instrument requires fine motor and coordination skills. Therefore the levels of a child's manual dexterity or balance are factors that might influence the musical learning process (Pierce, 2007). Additionally, taking into account the role of movement when interacting with the Music Paint Machine, it was estimated that the fine and gross motor skills of the children were factors that could influence the children's interaction with the system and, consequently, their learning process. Furthermore, research has indicated that motor abilities have an effect on musical abilities. For example, in observational studies by Gruhn (1999, 2002), it was demonstrated that those children who can sing in tune more properly and can keep a regular steady beat also exhibit a well coordinated body control and move in space more smoothly in a continuous sustained flow.

In this study we used the Movement Assessment Battery for Children 2 (M-ABC2) (Henderson, Sugden, & Barnett, 2007). This test provides quantitative and qualitative data about a child's performance of several age-appropriate tasks, subdivided into three subsections: Manual Dexterity, Ball Skills, and Balance (Static and Dynamic). The test is designed to identify and describe the motor functioning across a range of fine and gross motor tasks among children 4–12 years old (T. Brown & Lalor, 2009). Scores are rated from 0 to 40 and higher scores indicate higher impairment. Score can be converted to percentile scores, which allow to categorize a child's performance via an easy to use 'traffic light' system: scores in the red zone (5th percentile or below) indicate motor impairment; scores in the amber zone (6th to 15th percentile) point at a motor skill level "at risk"; scores in the green zone (16th percentile and above) indicate a normal level of motor skills.

Primary & Intermediate Measures of Music Audiation (PMMA & IMMA)

Music aptitude is usually defined as the potential or capacity for musical achievement (Gordon, 2007). According to Gordon it is a product of both innate potential and environmental influences. A child is born with this potential but the child's environment and early musical experiences determine the degree to which this potential is actualized. Up until the age of nine, music aptitude is believed to be dynamic and fluctuating according to the environmental influences (Gordon, 2007). Early exposure to music but also music instruction can play an important role in actualizing the musical potential of a child.

In this study we used the Primary and Intermediate Measures of Music Audiation to measure music aptitude. Both tests probe auditory discrimination skills on the basis of a same-different judgement. Children are presented with forty pairs of short melodic patterns for the tonal test and forty pairs of short rhythmical patterns for the rhythm test. Children have to indicate whether the patterns are the same or different, by drawing a circle around pictures on an answer sheet (see Figure 10.5).

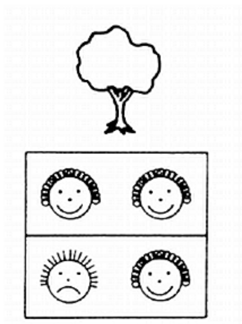


Figure 10.5. An example of a pictorial representation used in the PMMA and IMMA. Each pair of melodic phrases has its own picture (e.g. tree or hand) and children draw a circle around the similar (laughing) faces (top) when they hear the two melodic phrases as sounding the same. They draw a circle around the dissimilar faces (bottom) when they hear the two melodic phrases as sounding different.

Whether these tests are actually a measure of innate aptitude or a measure of learning and achievement is still under debate (Norton, et al., 2005). In this study, the test is used for two reasons. The first reason is to map the listening skills of the children prior to instruction. In this way the children's music aptitude could be integrated in their profile. The second reason was to measure the influence of the Music Paint Machine on the development of music aptitude. According to Gordon, music aptitude does not stabilize until the age of nine and the importance of quality in classroom formal music instruction particularly through the third grade can not be overestimated (Gordon, 1986).

10.2.5. Procedure

10.2.5.1. Researcher as teacher

In this study, the researcher acted as teacher. This was decided for a practical reason and for a substantive reason.

The practical reason concerned the difficulty to find a teacher who wanted to devote a whole year of his teaching to the present research project. This might be explained by a number of factors. First, learning to use the technology and developing good practices with it would require quite an amount of time and effort from the teacher. This has been found to be an obstacle for teachers (e.g. OECD, 2010). Second, collaborating in this project would interfere with the regular curriculum. Third, as pointed out by Woody (2004) and Karlsson & Juslin (2008), teachers are often reluctant to academic research.

The substantive reason concerned the unique position the teacher-researcher holds. According to Regelski, researchers are too often “outsiders” from the field and, consequently, are prevented from identifying and exploring issues that are important to teachers (Regelski, 1994). In contrast, when the teacher is the researcher it becomes possible to, in a privileged way, gather, interpret and use research-generated data about the different aspects of teaching and learning. As an involved observer, the teacher-researcher is uniquely positioned to provide an insider‘s view that brings with it an unique combination: the power of first person perspective, the limitations of the participant perspective, and the balancing act of simultaneously teaching and researching (Campbell, 2011).

10.2.5.2. Recruitment and assignment of participants

This study targeted at children from the first and second grade who did not receive any formal (instrumental) music instruction before the start of this study and who did not play or had been playing a musical instrument. These selection criteria were used for two reasons. First, it was important not to interfere with local music schools’ recruiting of students (from the age of nine). This was important in order to maintain a good relationship with the school principal and to establish a possible collaboration that could provide continuation of the instruction after the experiment had finished. Second, it was important that the children had no previous experience in playing an instrument in order to rule out this experience as a possible confounding variable.

Participants were recruited through a large-scale information campaign. The principals of all compulsory primary schools in the area of our university were requested to forward a letter with information on the program to the parents of students between 6 and 8 years old. They were also asked to clearly display a poster that was attached to the mail, in a prominent place of the school. A website was created to provide more detailed information on the program, with regard to the experimental nature, enrolment procedures, practical matters (e.g. location, important dates) and the type of instrument that was going to be used. Both the information letter and the website specified the requirements to enrol for the program and the compensations participants would receive.

Participants who completed the study were compensated by a refund of the enrolment fee at the end of the program and by reduction on the cost of the instrument. At the beginning of the program, the instrument was paid at full price. The reduction was refunded at the end of the program. It was clearly stated that participants could redraw from the study at any moment.

There was no selection procedure. Parents, who considered enrolling their child, contacted the researcher. A meeting was organised during which the necessary information was provided so parents could make an informed decision on enrolling their child for the program. All parents signed an informed consent.

10.2.5.3. Questionnaires and tests prior to instruction

Prior to instruction, three questionnaires relating to the participating children's self-regulation skills, home musical environment and personality were administered to the children's parents. Each parent completed the questionnaires separately, with the exception of one case in which one of the parents did not sufficiently speak Dutch. In this case the parents completed the personality questionnaire together. The home musical environment had an online and a paper version; both other questionnaires were only administered on paper.

During the two weeks before the instruction started, the children participated in two pre-tests. First, the PMMA was administered to all children. Due to practical requirements, namely the amount of pre-tests and the parents' activity schedule, the tonal and rhythm test were administered on the same day. Between both tests a short break was foreseen with a little physical activity to relax and facilitate concentration afterwards. Second, the children participated in the M-ABC2. Two professionals, holding a master degree in Physical therapy and motor rehabilitation and having a large experience with the test, administered the test.

10.2.5.4 Instruction

In this section we describe the organisation of the lessons, the approach of the instruction, and the learning path.

Organisation of the lessons

Lessons were given once a week for a period of 9 months, with the exception of school holiday weeks. As mentioned earlier, the researcher (first author) provided the instruction to the children. Children attended class in groups of three and received instruction during approximately one hour. The first two groups received regular instruction; the second two groups received instruction with the Music Paint Machine. The content of the lessons was the same for the four groups. Between the two control groups and the first experimental group, a break was inserted to setup the Music Paint Machine.

Approach of the instruction

Lessons were based on an aural approach in which the children were guided from sound to sign on the basis of a carefully designed learning path. The children learned to play by ear, starting from well-known children's song. They first learned to sing the songs, while preparing their instrumental performance on the basis of the song's musical building blocks (e.g. melodic or rhythmic patterns). For example, the first song, "Klap klap" (see Figure 10.6), was based on the notes e and g and on two rhythmic patterns.

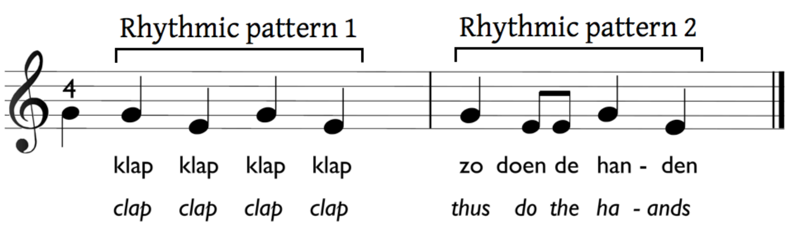


Figure 10.6. The first song the children learned to play on the clarineo.

First, children sang and clapped the rhythm. In the mean while they played exercises with the note e and g and they played the rhythmical patterns on one note. Once they could sing the song and were accustomed to the building blocks of the song, they learned to play the song on the clarineo, by ear. Notation was introduced only when the children were able to play the song. Once they knew to play a song, they learned to play the same song on different notes.

Both improvisation and composition were an integral part of the lessons. The building blocks of songs were used for example to freely improvise, to play scales, to compose rhythmic sequence on which they could improvise a melodic contour, and to compose their own songs. Learning to compose was based on a step-by-step method that was designed by the teacher for this study.

Children were stimulated to use the acquired knowledge and skills on the basis of different games. For example, in one game the children engaged, together with the teacher, in a musical conversation. Musical phrases were played as if they were statements, questions or exclamations in order to simulate a conversation. Another example was the games with flashcards that contained specific tasks, related to the different musical parameters (melodic contour, rhythm, dynamics) or emotions (see Figure 10.7). One child picked out a card, performed the task and the other children had to imitate or guess which card had been drawn.

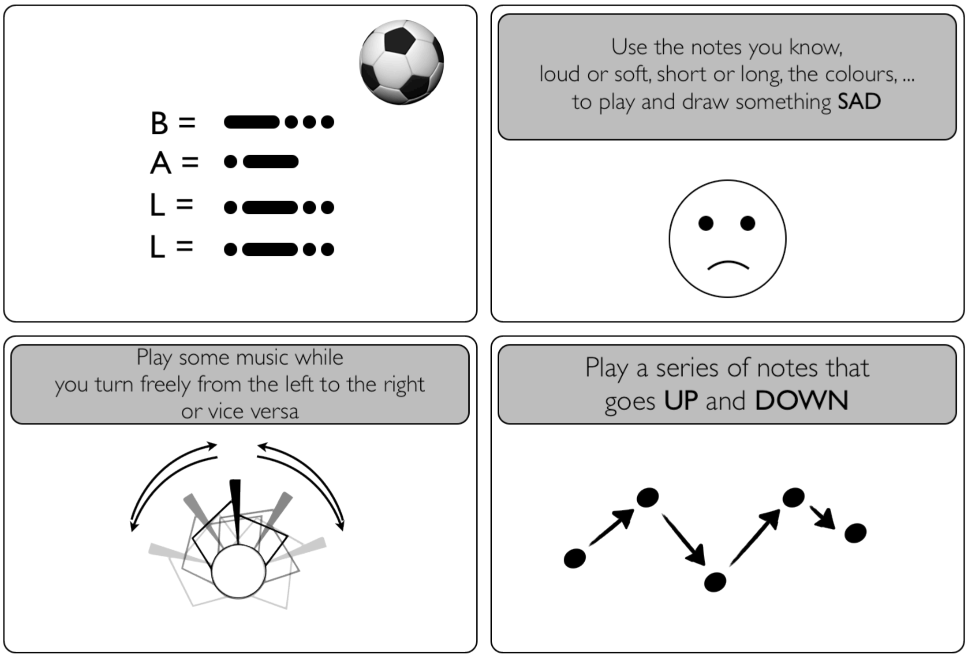


Figure 10.7. Four examples of flashcards that were used in musical games to develop musical skills and to stimulate musical creativity. Some flashcards used Morse code to learn about note duration and rhythm (top left), to develop children's emotional expression (top right), to use movement (bottom left) or to be creative with melodic contour. This exercise could be done with or without the Music Paint Machine.

To support instruction and practice, a website was designed that contained practical information, announcements, materials from the lessons and audio clips of the songs and exercises, extra material (songs and exercises), a page on how to practice, different links, a fun page with colouring pages, and a portfolio page with the children's own compositions and drawings (see: klarinetinitiatieklas.weebly.com[7]).

Learning path

A methodically organized learning path was constructed on the basis of the weekly teaching experience with the Music Paint Machine. For every lesson, short-term learning goals were determined (e.g. learn a new note, a new rhythm, dynamics) as steps towards long-term learning goals (e.g. being able to play all notes within the chalumeau register, being able to visually/aurally recognize a pre-defined range of rhythms, being able to play with different dynamics). In function of these learning goals, didactic practices were designed in which the use of the Music Paint Machine was implemented. For every lesson a script was made, containing the structure and content of the lesson.

The learning path consisted of incremental steps, going to the basics of musical parameters and moving gradually towards notation. For example, before rhythms were introduced, children learned about short and long notes; then they learned to make rhythmic patterns with short and long notes (e.g. based on morse code); this was coupled to the rhythmic patterns of the songs; then they learned about beats as a way to measure note duration; this was followed by the introduction of rhythmic motives based note values.

The structure and content for all groups was kept the same as much as possible. This was done to enable a maximal comparison of the control and treatment groups. Appendix C contains examples of the materials for the lessons.

10.2.5.5. Repeated measures

The PMMA was administered as a pre-test and repeated three times throughout the study, approximately each three months. To accurately follow the procedures as prescribed in the manual, the specific directions for administering both tests were translated to Dutch and strictly followed. Children with a PMMA percentile score above 80, were administered the IMMA as prescribed in the manual (Gordon, 1986). Due to practical considerations (mainly parents' schedule) it was not possible to administer the IMMA immediately after the PMMA. Therefore, sometimes the IMMA was administered the next time. This complicated the data because PMMA and IMMA scores cannot be compared (Gordon, 1986).

[7] Password can be provided by the author upon request.

10.3. Data analysis and results

10.3.1. Calculation of scores and descriptive analysis

Before statistical analysis was performed on the data, different scores were calculated. Scores from the standardized tests (P/IMMA, M-ABC2) were converted to percentiles. The P/IMMA scores were also assigned to categories following Gordon's categorization into low (< 20^{th} percentile), average (between 20^{th} and 80^{th} percentile) and high percentile (> 80^{th} percentile) score (Gordon, 1986). For the Schwarzer self-regulation scale and for the personality questionnaire (Fruyt & Vollrath, 2003), we used the mean score of both parents. For the HME questionnaire, a score was calculated for the overall degree of musical activity (DMA). This score was also based on the mean score of both parents. Table 10.6 presents an overview of measures and variables.

After calculating the different scores, mean scores and standard deviations were calculated for the whole sample and for the separate groups. In the case of the measures of music audiation, it was not possible to calculate the mean score for the whole group because not all children were administered the same test and because the scores of different tests cannot be compared (Gordon, 1986). Therefore within each group a distinction was made between the means for PMMA scores and the means for the IMMA scores.

10.3.2. Inferential statistics

To measure the influence of home musical environment, personality, self-regulation skills, motor skills, home study and classroom experience on developmental music aptitude, a correlation analysis (Pearson's *r* and Spearman's *rho*) was performed. To detect possible significant differences between the control and treatment group, a Mann-Whitney U test was performed.

Table 10.6. Measure (left), variables (middle) and calculated variables of this study

M-ABC2 motor skills	Manual dexterity Ball skills Balance Total score	Percentile scores
P/IMMA music aptitude	Tonal Rhythmic Composite (music)	Percentile score level ($_L$-M-^{H})
SSRS - self-regulation		
HME home musical environment	Parents' musical activity Child's musical activity Siblings musical activity Parents' beliefs on practice	Degree of musical activity (DMA)
HiPIC personality	Fear Self-confidence	emotional stability
	Energy Expressiveness Optimism Shyness	extraversion
	Creativity Intellect Curiosity	openness
	Concentration Perseverance Order Achievement striving	conscientiousness
	Altruism Dominance Egocentrism Compliance Irritableness	agreeableness
HS Home study	Minutes per day	Average per dayper year Average per week per year Average per day per trimester Average per week per trimester Average days per week Missing values
CEQ	Enjoyable Instructive Understandable Difficult Successful	Mean per year Mode per year Mean per trimester Mode per trimester Missing values

10.3.3. Results

Schwarzer Self-regulation scale (SSRS)

For the descriptive analysis of the SRSS, we used the mean of parental scores. This was decided on the basis of the results obtained by the Wilcoxon signed rank test, which did not show a significant difference between the responses of the parents. The descriptive statistics are presented in Table 10.7.

Table 10.7. Means and standard deviations of the Schwarzer Self-regulation scale. The response format of the questionnaire was as follows: (1) not at all true, (2) barely true, (3) moderately true, (4) exactly true.

	SSRS	
	M	*SD*
All	2.63	.35
Control Group	*2.69*	*.20*
Group A	2.82	.12
Group B	2.57	.21
Treatment Group	*2.69*	*.38*
Group C	2.95	.05
Group D	2.43	.40

A Mann-Whitney U test was performed to compare the control and treatment groups. Self-regulation scores from the control group (*Mdn* = 5.5) did not differ significantly from the scores of the treatment group (*Mdn* = 5.7), U = 13.50, z = -.726, $p = .468$, r = -.21.

Home musical environment (HME)

The HME questionnaire aimed at mapping the musical behaviour of the children's family. Questions (n = 53) focused on playing, singing, listening, material at home and beliefs on practice.

Six out of twenty-four (25%) parents played a musical instrument (3 mothers, 3 fathers) but they rarely played it in the presence of their child. One father stated that he plays every day in presence of his child; one father did this once a week.

Most parents (83%) said they sing with their children. Mothers appear to sing more often (*Mo* = "a few times a week") with their children than the fathers (*Mo* = "once a week or less").

Most of the parents (70%) also said they dance with their child, but this seems to occur rarely. Only two mothers reported they dance with their child once a week. The other parents do it less than once a week or never.

With regard to beliefs about the children's practice behaviour, responses showed a difference between mothers and fathers. Mothers seemed more convinced that their child would need help to practice but that they also could help their child practicing. They were less convinced that their child would self-initiate practicing. A Mann Whitney U test showed a significant difference between the mothers of the control group and of the treatment group with regard to whether their child should be helped to practice (U = 5.50, $p < .05$). Mothers of the control group were more convinced that their child would need help. This is also reflected in the results on the home study data. The mode of the control group with regard to who helped the child when practicing, was "helped by the mother", while for the control group the mode was "no help".

Only three children (one in the control group, two in the treatment group) had one ore more brothers or sisters that play a musical instrument. These children heard their brothers or sisters play a few times a week. With regard to the listening behaviour of children, parents tended to disagree. In most cases, fathers indicated a less frequent listening behaviour to the various genres. However, looking at the cumulative percentages, both parents' responses suggest that most children listen to music less than one hour a day (mothers: 75%, fathers: 66,7%). Both parents agreed that children mostly sing on their own at home with (*Mo* = "regularly") or without (*Mo* = "once in a while") different kinds of media (e.g. TV, iPod). Both parents also agreed that children dance mostly on their own.

In addition to the descriptive analysis, a score was calculated for the degree of musical activity (DMA). This score was based on twenty-two items of the questionnaire, all related to activities that involved the child (frequency of singing with the child, of dancing with the child, of going to concerts with the child, the child's listening, singing and dancing behaviour). Scores were summed and reduced to a score between one and five. Because it was assumed that the presence of musical material in the home might stimulate musical activity, a differentiation was made between de DMA with present musical material and without. In both cases a difference was found between the control group and the treatment group (see Table 10.8). However, this difference is only indicative; a Mann-Whitney U test did not show a significant difference (see Table 10.9). But while no significant difference was found between the control and treatment group, a Mann-Whitney U test showed a significant large effect of gender on the DMA score, $U = 3.000$, $Z = -2.410$, $p < 0.05$, r =-0,60. On a scale of one to five, the medians of girls and boys were 2.90 ($SD = .21$) and 3.30 ($SD = .23$) respectively. Within this sample, boys were more musically active.

Table 10.8. Means and standard deviations of the Degree of Musical Activity (DMA).

	Without musical material		With musical material	
	M	*SD*	*M*	*SD*
All	3.08	0.35	3.03	0.30
Control group	3.22	0.30	3.15	0.25
GrA	3.04	0.22	3.02	0.21
GrB	3.39	0.28	3.28	0.25
Treatment group	2.93	0.36	2.91	0.32
GrC	2.89	0.25	2.86	0.22
GrD	2.98	0.51	2.96	0.44

Table 10.9. Results of the Mann-Whitney U test.

Test Statistics[a]

	DMA without musical material	DMA with musical material
Mann-Whitney U	9.000	10.000
Wilcoxon W	30.000	31.000
Z	-1.441	-1.286
r	-0.42	
Asymp. Sig. (2-tailed)	.150	.199
Exact Sig. [2*(1-tailed Sig.)]	.180[b]	.240[b]

Personality (H*i*PIC)

The questionnaire on personality was completed by the parents of the children. To see whether there was a significant difference between the responses of fathers and mothers, a Wilcoxon signed rank test was performed. No significant differences were found. Therefore it was decided to use the mean of parents' scores for further analysis.

In table 10.10 the descriptive statistics of the five personality domains are presented.

An observation of the data suggests slight differences between the control and treatment groups. Especially when looking at the data of the four groups, instead of comparing the means of two pairs (treatment and control) of groups. Group D appears to stand out from the other groups (see Figure 10.8).

However, using a Mann-Whitney U test, no significant differences were found between the control and treatment groups.

On the other hand, a Mann-Whitney U test showed a significant large effect of gender on self-confidence, U = 4.500, Z = -2.166, p < 0.05, r =-0,62. The medians of girls and boys were 24.75 (SD = 3.43) and 29.25 (SD = 1.58) respectively. Gender had also a significant large effect on the emotional stability, U = 3.000, Z = -2.406, *p* < 0.05, *r* =-0,69. The medians of girls and boys were 45.00 (*SD* = 6.35) and 53.75 (*SD* = 3.28) respectively. In this sample, boys seemed more self-confident and more emotionally stable.

Table 10.10. Mean and standard deviations of the five personality domains as measured by the H*i*PIC.

	Emotional Stability		Extraversion		Imagination		Benevolence		Conscientious -ness	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
ALL	49,63	6,58	119,96	17,41	95,71	12,62	139,17	10,62	107,17	21,38
Control	51,67	6,01	119,33	23,21	99,17	11,29	141,50	12,51	107,17	12,86
A	52,17	4,86	110,00	17,54	97,50	14,76	142,33	14,58	115,50	10,11
B	51,17	8,13	128,67	27,89	100,83	9,61	140,67	13,29	98,83	10,13
Treat	47,58	7,01	120,58	11,29	92,25	13,94	136,83	8,87	107,17	28,99
C	49,00	6,54	119,50	14,18	101,67	6,37	142,00	4,58	119,17	25,31
D	46,17	8,61	121,67	10,69	82,83	13,38	131,67	9,78	95,17	32,06

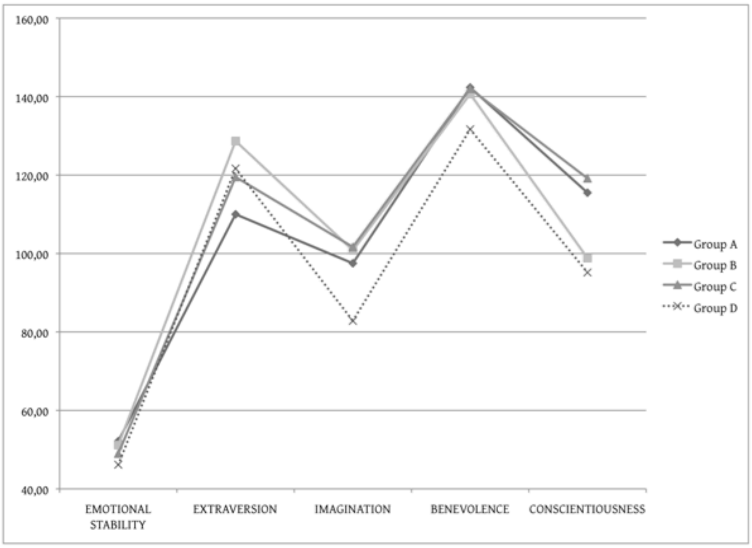


Figure 10.8. Means per group of the five personality domains as measured by the H*i*PIC.

Movement assessment battery for children (M-ABC2)

The children's scores on the motor skills test indicated that most children had a normal level of motor skill. One child from the control group was at the "at risk" level. Both control groups had a mean total score slightly below the mean total score of the total sample (see Table 10.11).

Table 10.11. Mean and standard deviations of the children's scores on the M-ABC2 test.

M-ABC2	*Manual Dexterity*		*Balls Skills*		*Balance*		*Total score*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
All	35.67	17.28	37.50	28.19	64.33	23.34	47.42	23.22
Control Group	*32.33*	*15.71*	*30.00*	*23.66*	*69.67*	*28.10*	*45.33*	*24.37*
Group A	38.67	19.63	17.00	17.44	75.67	33.72	44.67	33.32
Group B	26.00	10.54	43.00	24.27	63.67	27.01	46.00	19.31
Treatment Group	*39.00*	*19.59*	*45.00*	*32.46*	*59.00*	*18.45*	*49.50*	*24.13*
Group C	46.00	19.31	38.67	39.26	50.00	13.00	48.67	31.18
Group D	32.00	20.95	51.33	31.18	68.00	20.95	50.33	21.94

Home study (HS)

On average, children practiced approximately 10 minutes a day (*M* = 9.83, *SD* = 2.0). Interestingly, for three groups the data show an increase of practice in the second trimester, followed by a decrease in the third trimester (see Figure 10.9). The fourth group show a continuous decrease in the amount of practice per day.

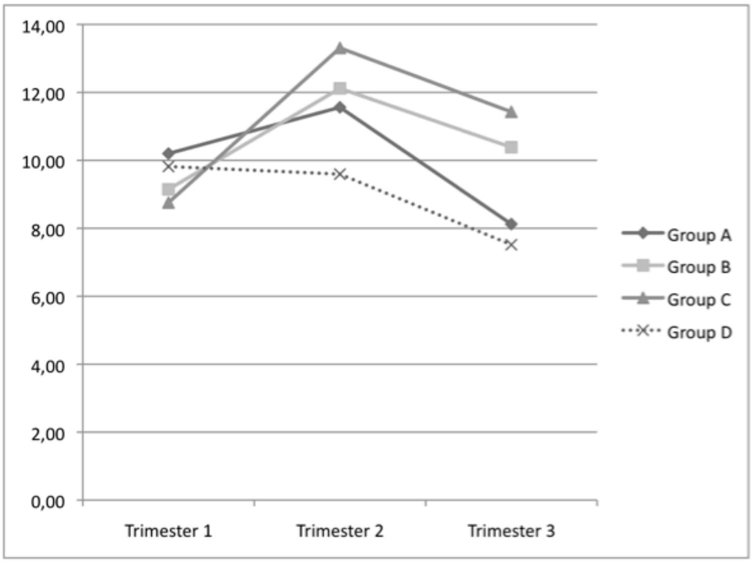


Figure 10.9. The amount of time children practiced on a daily basis

The data show a slight but insignificant (*U* = 14.000, Z = -.641, *p* = .522) difference between the control group (M = 9.51, *SD* = 1.15) and the treatment group (M = 10.14, *SD* = 2.69) (see Table 10.12).

Table 10.12. Means and standard deviations of the home study data

	HS	
	M	*SD*
All	9,83	2,00
Control Group	9,51	1,15
Group A	10,05	1,23
Group B	8,98	0,98
Treatment Group	10,14	2,69
Group C	11,23	2,68
Group D	9,05	2,71

While no significant difference was found between the control and treatment group, a Mann-Whitney U test showed a significant large effect of grade, U = 1.000, Z = -2.6800, $p < 0.05$, r =-0,77. The medians of grade 1 and grade 2 were 10.78 (SD = 1.54) and 8.60 (SD = 1.47) respectively. Appearantly, children from Grade 1 practiced more.

Next to providing data on the amount of practice time, parents also reported who helped the child while practicing. Children were mostly helped by their mother (32% of all entered data). The mode of group B (control group) and of group D (treatment group) was "not helped" for the whole year. These data give an indication of the engagement of the parents.

Classroom experience

After every lesson, the children completed a questionnaire comprising five questions related to how they experienced the lesson. Table 10.13 presents the descriptive statistics.

Table 10.13. Means and standard deviations of the CEQ.

CEQ	*Enjoyable*		*Instructionable*		*Understandable*		*Difficult*		*Succesful*	
	M	SD	M	SD	M	SD	M	SD	M	SD
All	1.48	.57	1.52	.40	1.69	.46	1.81	.51	1.98	.82
Control Group	1.19	.09	1.37	.18	1.85	.39	1.88	.54	1.72	.27
Group A	1.14	.05	1.23	.11	2.03	.16	2.17	.56	1.73	.09
Group B	1.23	.10	1.51	.08	1.68	.51	1.60	.43	1.70	.41
Treatment Group	1.77	.70	1.67	.52	1.53	.50	1.73	.51	2.24	1.12
Group C	1.24	.31	1.43	.65	1.20	.25	1.61	.72	1.88	1.36
Group D	2.31	.53	1.91	.29	1.85	.48	1.86	.30	2.60	.94

A Mann-Whitney U test was used to compare the results from the control and treatment groups. No significant differences were found. However, a significant large effect of grade on whether the children experienced the lesson content as difficult (difficulty), $U = 3.500$, $Z = -2.719$, $p < 0.05$, $r = -0{,}78$, was found. On a Likert scale of 1 (*agree*) to 4 (*disagree*), the medians of grade 1 and grade 2 were 1 ($SD = .0$) and 2 ($SD = .83$) respectively. This means that children from Grade 2 perceived the lessons as more difficult. However, the large standard deviation of Grade 2 children's results has to be taken into account.

Grade was also found to have a large effect on whether the children believed they had the feeling they did well, $U = 5.000$, $Z = -2.289$, $p < 0.05$, $r = -0{,}66$. On a Likert scale of 1 (agree) to 4 (disagree), the medians of grade 1 and grade 2 were 1 ($SD = .83$) and 2 ($SD = .83$) respectively.

Measures of Music Audiation (PMMA & IMMA)

The results of the PMMA pre-test show moderate scores in most groups. In table 10.14 the mean percentile scores are presented.

Table 10.14. The mean scores and standard deviations of the PMMA pre-test.

PMMA	*Tonal*		*Rhythmic*		*Composite*	
	M	*SD*	*M*	*SD*	*M*	*SD*
All	60.75	38.86	62.83	23.34	62.08	30.45
Control Group	63.50	44.67	74.50	9.71	69.00	32.16
Group A	***89.67***	*8.33*	***80.00***	*6.00*	***88.00***	*5.00*
Group B	*37.33*	*53.52*	*69.00*	*10.44*	*50.00*	*38.43*
Treatment Group	58.00	36.18	51.17	27.89	55.17	29.85
Group C	*49.33*	*39.51*	*48.00*	*15.10*	*49.33*	*24.34*
Group D	*66.67*	*38.55*	*54.33*	*41.06*	*61.00*	*39.15*

An initial difference exists between the control group and the treatment group, showing a moderately higher music aptitude for the control group. This difference is larger with regard to the rhythmical aptitude. Standard deviations of both the control and treatment groups are rather large, indicating the heterogeneity of the group. Clearly, Group A stands out with a high score (80^{th} percentile or above) for both tonal and rhythmical tests. The standard deviation of this group was rather small in comparison to the other groups, indicating the homogenous nature of this group. However, when the Mann-Whitney U statistic was calculated to determine whether there was any statistically significant difference in the pre-test scores, no statistically significant difference was found between the control and treatment group.

With regard to the development of the children's music aptitude, differences can be found between the control and treatment groups. Table 10.15 shows the scores of both PMMA and IMMA when categorized as low (1), average (2) or high (3).

Table 10.15. Scores of both the PMMA (regular) and IMMA (italic) transformed into three categories: low score (1; 20th percentile or lower), average score (2; between 20th and 80th percentile), high score (3; 80th percentile or higher) (3).

student ID	*Tonal*				*Rhythmical*				*Composite*			
	T1	**T2**	**T3**	**T4**	**R1**	**R2**	**R3**	**R4**	**C1**	**C2**	**C3**	**C4**
1	3	3	*3*	*3*	3	3	*3*	*3*	3	3	*3*	*3*
2	3	3	*3*	*3*	3	3	*3*	*3*	3	3	*3*	*3*
3	3	*3*	*3*	*3*	2	*2*	*2*	*1*	3	*3*	*3*	*2*
4	1	3	*3*	*3*	2	3	*2*	*3*	2	3	*3*	*3*
5	3	*3*	*3*	*3*	2	*3*	*3*	*3*	3	*3*	*3*	*3*
6	1	2	3	*3*	2	2	3	*3*	1	2	3	*3*
7	3	3	*3*	*3*	2	3	*3*	*3*	2	3	*3*	*3*
8	1	1	1	2	2	2	2	2	2	2	2	2
9	2	2	3	3	2	2	2	2	2	2	2	2
10	2	2	1	2	1	2	1	2	1	2	2	2
11	3	3	*3*	*3*	3	3	*3*	*3*	3	3	*3*	*3*
12	2	3	3	*3*	2	2	2	*3*	2	2	3	*3*

In the control group, two children were administered the IMMA already from the second test and additionally the other children from the third test. The sixth child of the control group also took the IMMA in the post-test. In the experimental group, three children were administered the PMMA throughout the whole study, which indicates that they did not reach the 80th percentile of the PMMA. Two children of the treatment group took the IMMA from the third test and one in the post-test.

These results also show that children with a high score from the beginning, except for one child (ID=3), keep scoring high in the next tests, regardless which test (PMMA or IMMA) has been administered. Children with a low score in the pre-test show a different result. Some children (ID = 4,6,12) have an increased score; some children (ID = 8,10) show a more stabilized score.

At the end of the nine months, most children (75%) were administered the IMMA test. Although scores of the PMMA and IMMA cannot be compared, the shift from PMMA to IMMA indicates that development music aptitude progressed. Three children (25%) were still administered the PMMA. The mediocre scores of the three children (all part of the treatment group) who were administered the PMMA throughout the whole study suggest a rather low aptitude of these three children. Yet, the high standard deviation has to be taken into account. One of the three children had a high score (93) for tonal aptitude. Table 10.16 shows the mean and standard deviations of the post-test.

Table 10.16. Mean and standard deviations of the post-test. Because results of the PMMA and IMMA cannot be compared, scores are differentiated.

	Tonal		*Rhythmic*		*Composite*	
	M	*SD*	*M*	*SD*	*M*	*SD*
CGr - IMMA	95.33	5.43	70.00	33.02	83.17	26.44
GrA	*96.33*	*2.31*	*63.33*	*50.58*	*74.67*	*38.70*
GrB	*94.33*	*8.08*	*76.67*	*5.77*	*91.67*	*5.77*
TGr - PMMA	56.33	33.95	50.67	19.01	45.33	26.08
TGR - IMMA	99.00	*0.00*	76.67	23.63	91.67	*10.12*
GrC - PMMA	*59.50*	*47.38*	*60.00*	*14.14*	*48.50*	*36.06*
GrC - IMMA	*99.00*	-	*95.00*	-	*98.00*	-
GrD - PMMA	*50.00*	-	*32.00*	-	*39.00*	-
GrD - IMMA	*99.00*	*0.00*	*67.50*	*24.75*	*88.50*	*12.02*

To investigate the influence of possible confounding variables, a correlation analysis was performed between the different measures and the P/IMMA scores. The analysis did not show many significant results. Interesting findings were:

- *a moderately strong positive correlation between the parents singing behaviour and the scores for the tonal pre-test:* children who's mother sings (r_s = .652, p < .05) and does it with her children (r_s = .652, p < .05) more frequently than others (r_s = .652, p < .05), had higher scores on the tonal subtest.

- *moderately strong correlations between the anxiety* (r_s = -.670, p < .05), *irritability* (r_s = -.649., p < .05) *and perseverance* (r_s = .584, p < .05) *aspects of personality and the scores for the tonal pre-test. More anxious and less persevering children had lower scores.*

- *a moderately string positive correlation* (r_s = .664, p < .05) *between the concentration aspect of personality and the rhythm pre-test. Children who's parents believe they have good concentration abilities scored higher on the PMMA rhythmic pre-test.*

10.4. Discussion

The aim of this study was to investigate whether the Music Paint Machine could positively affect the developmental music aptitude of the children who learned to play the clarineo. It was hypothesized that providing instruction with the Music Paint Machine contributes to the establishment of a rich musical environment in which the development of music aptitude can be stimulated. We used the PMMA and IMMA to measure music aptitude. Although for most children a progress in the scores was found, some children's scores showed a fluctuating effect and one child's score degraded continuously. No significant differences between the control and treatment group were found. However, results suggested that singing behaviour has an effect on the scores of the PMMA. The positive effect of singing on the developmental music aptitude was shown in a study by Tai (2010). Results also suggested a relationship between facets of personality (e.g. concentration, perseverance) and the PMMA score. Personality has been linked before to music aptitude, in particular to Cattell's personality factor intelligence (Schleuter, 1972).

Due to the small sample size and the mixture of PMMA and IMMA scores in the post-test, it was not possible to perform a correlational analysis to investigate the relationship between the potential confounding variables (e.g. HME, personality). Therefore, whether the changes that occurred in the children's scores are due to instruction with the Music Paint Machine, remains inconclusive. Further investigations are needed. This study has provided didactic practices that can be used to conduct future experiments.

While the primary aim of the study was to test the effectiveness of the system, the nature of the study was explorative. Conducting the study led to insights with regard to the focus of the study (effectiveness of the technology) and to the adopted method (design, measures). In the next sections, these insights are discussed.

10.4.1. The transformative impact of the Music Paint Machine: preliminary findings based on an auto-ethnographic reflection

Conducting this study has led to the insight that an educational technology is much more than an independent variable that is inserted in the instructional process and possibly induces an amplicative effect. Here, the position of the researcher as teacher was essential to experience the transformative impact of the technology on instruction. In this section we reflect on the transformative impact of the Music Paint Machine, on the basis of a subjective personal introspection (Rod, 2011; Woodside, 2004). We are aware of the highly subjective nature of this reflection. However, within the scope of this paper, we believe it suffices as an illustration of the way that using the system influences different aspects of instruction. Future work entails a microanalysis of the video footage of a selection of the one hundred twenty one-hour lessons that were given. In function of an in-depth investigation of these preliminary findings that were obtained through an auto-ethnographic reflection, a coding system is currently under development based on the work of different scholars (Colprit, 2000; Custodero, 2005; Duke, 1999a, 1999b; Duke, et al., 1998; Flanders, 1970; Heikinheimo, 2009; Karlsson & Juslin, 2008; Rostvall & West, 2003, 2008; Welch, et al., 2005; Zhukov, 2004).

One example of the impact of the system concerns the *proxemics* of teaching and learning, i.e. the use of the classroom space. Proxemics has been acknowledged as an important aspect of teaching and learning (Jordon, 2001; F. V. Lim, O'Halloran, & Podlasov, 2012). In the beginning the children's engagement with the system was an individual experience during which the teacher kept rather distant, preventing other children from interfering with the child that was interacting with the system (see Figure 10.10).

Figure 10.10. In the beginning of the study, the teacher kept distance while a child was interacting wit the Music Paint Machine. Other children had to wait their turn, often seated on a chair.

Additionally, the setup of the system (colour mat in the middle of the classroom, Kinect®) restrained the way the children and the teacher could move in the classroom. They could not walk in front of the Kinect® or come too close to the child who was on the colour mat. Therefore the children were often queued up at a fixed place (e.g. sitting on a chair) in the classroom. However, gradually the teacher started to connect more to the child and to involve other children to the extent that engaging with the system became more and more a collaborative experience (see Figure 10.11).

Figure 10.11. Gradually, using the Music Paint Machine became a collaborative musical activity in which other children and the teacher participated.

Another example concerns the behaviour of the children. Sometimes they did not want to leave the colour mat to start a next part of the lesson and kept on engaging with the system. Or they were attracted by the computer and the interface (e.g. seeing themselves on the screen as captured by the Kinect®), even to the extent that some children repeatedly tried to change things on the computer (close windows, click on buttons). Additionally, the children who were enthusiastic about the Music Paint Machine often jumped wildly on the colour mat, which as a proto-type was still rather fragile (see Figure 10.12). When this kind of behaviour was happening too much, the teacher had to intervene to "rescue" the mapping (software interface) or the mat and sometimes even verbally reprimand a child.

Figure 10.12. Children having "fun" on the mat.

A final example to illustrate the impact of the system concerns the timing or pacing of the lesson. Pacing is concerned with the amount of time the teacher spends on a certain learning content or with the speed of the teacher's verbalizations (Duke, et al., 1998). Because of the design and the aim of keeping the learning content the same for the control and the experimental group, the use of the Music Paint Machine put pressure on instructional pacing, out of the concern to have treated all the planned learning content. Furthermore, sometimes the system or the mat malfunctioned, requiring time for rebooting or repairing (see Figure 10.13). On other occasions the sessions with the system took more time than foreseen during the preparation of the lesson.

Figure 10.13. Problems with the hardware sometimes introduced constraints on instructional pacing.

These examples illustrate the impact of the educational technology on the different components of instruction, namely the teacher, the learners and the interaction between both. Throughout the year the teacher became more and more aware of a qualitative change in his own thinking, acting and reacting while teaching with the Music Paint Machine. This experience led to insights on how to conduct educational technology research. In particular, the initial aim of testing the effectiveness of the system on the basis of measuring learning outcomes or aspects of musical development (e.g. music aptitude) came under scrutiny. Realizing that the possible effectiveness of the system not only depends on its features (e.g. providing feedback, using movement) but also, and maybe even mostly, on its impact on instruction, it is important to establish a methodology that allows to study the impact of technology on the processes that underlie instruction. In the next section, we elaborate on the design of this study, taking into account the need to focus on the transformative impact.

10.4.2. An evaluation of the method

Design

The design of this study, with its pre-test/post test and treatment methodology (technology as independent variable), was a typical design for the evaluation of the effectiveness of a tool (Papert, 1987). However, the weekly experience of teaching with the Music Paint Machine made clear that the technology had an impact on aspects of instruction such as proxemics, learner-teacher interaction, and instructional pace. This led to the insight that measuring the effectiveness of a tool is not a mere question of measuring learning outcomes when using the system or not. Therefore, rather than using a pre-test post-test design in which the outcome (product) of the instruction (e.g. developmental aptitude) is emphasized, empirically evaluating an educational technology might benefit from an approach that focuses on the processes that underlie instruction. These findings mirror the critical accounts of the instrumental view on technology (e.g. Mize & Gibbons, 2000; Schnotz & Lowe, 2003). A next step therefore is to conduct an observational study in which the behaviour of both the children and teacher, the structure and the content of the lessons are investigated on the basis of an elaborated coding system.

Although this study would have lent itself to an action research approach in which the teacher-researcher engages in a cyclical process of change (plan, act, observe, reflect), it was chosen not to adopt this method. The aim of action research is to use improve practice by integrating research and action in a series of flexible cycles (Somekh, 2006). However, this would increase the impact of the research on the lessons, thereby making it more difficult to clearly determine how the actual impact of the technology. Therefore, the data of the different tests were not used to shape instruction.

Instead of adopting an action research approach, we used quasi-experimental design. Throughout the course of this study it became clear that the use of a control and treatment group is a valid way to conduct such a study. It enables the comparison of instructional processes with or without the educational technology and this might reveal important aspects of the transformative impact of the technology. Such comparison has been undertaken in a study by Welch and colleagues (Welch, et al., 2005). In their study, two teachers used the Winsigad system to provide singing instruction. Each teacher gave instruction to four students, two of which received instruction with the technology. Results suggested that the teachers developed proper ways of using the technology. Differences were found between lessons with or without the technology. We believe this is a promising approach to study the transformative impact of the technology. We have adopted a similar approach. The difference lies in the use of the repeated measurement of music aptitude, home study and classroom experience and of the different pre-test to map possible confounding variables. Also instruction with or without the Music Paint Machine was based on the same instructional content. Although the teacher-researcher was fully aware (1) of the necessity to individually differentiate the content of the lessons and (2) of the necessity to adapt the lessons according to new teaching opportunities that arose spontaneously during a classroom event, it was chosen to keep the content the same as much as possible. This was done to enable a comparison between the instruction with or without the educational technology. While this approach seems to fully adhere to the instrumental view, it nevertheless was found to be a fruitful approach. Lessons were prepared from week to week and the content was decided on the basis of the possibilities with the Music Paint Machine. Because the learning goals were the primary concern, this way of working lead to a rethinking of instrumental didactic practices and to the development of new didactic materials that could be used both with and without the technology. In this way the transformative impact of an educational technology was felt throughout the preparation of the lessons. These findings are in line with the approach of Koehler and colleagues (M. Koehler, Mishra, Yahya, & Yadav, 2004; M. J. Koehler & Mishra, 2005a, 2005b; see also: Polly, 2011).

Measures

This research has pointed out the difficulty of using the PMMA and IMMA in the context of this study. First, when children score very high from the beginning they need to be administered the next test (IMMA) and consequently scores can no longer be compared (Gordon, 1986). This hinders statistical analysis. Second, we believe that the results of the test might be influenced by other elements such as personality (e.g. anxiety, perseverance, concentration) or motivational aspects. The results of the correlation analysis pointed in this direction. Therefore, next to mapping possible confounding variables (e.g. personality), further analysis (e.g. observational analysis) is needed to take into account possible influencing factors. Despite this limitation, it was estimated that both the PMMA and IMMA still might be valuable instruments within research on the use of educational technologies. Rather than being used as repeated measures, the test might be used to select and group children and to adapt the content of instruction. In particular with the Music Paint Machine, an interactive music system that allows for different uses, this would be a viable way to proceed in future research.

The questionnaire on home musical environment (HME) provides useful information. However, because of the small sample size it could not be tested on its reliability. The questionnaire needs to be further developed and tested on its reliability and validaty on the basis of the data of a large sample size. We also believe that in future work a child friendly version of the questionnaire needs to be developed so that the children can also complete a HME questionnaire to complement the responses of the parents. This also counts for the questionnaire on self-regulation skills.

10.4.3. Limitations of the study

One limitation of this study concerned the sample size. With regard to the goal of this study, i.e. to evaluate the effectiveness of the Music Paint Machine in nurturing the developmental music aptitude, the sample size was rather small. In this case inferential statistics such as the Mann-Whitney U test, will only consider large effects statistically significant, while the relatively small differences between the groups might still be meaningful.

Another limitation of the study was the time-consuming combination of being both researcher and teacher. It was not possible to keep a diary or to organize interviews with both the students and the parents. To a certain extend these limitations were overcome by the different questionnaires. However, future work needs to consider the use of teacher reports and interviews.

A final limitation of the study was the fact that children could not use the system at home. Consequently, using the system was limited to the sessions during instruction. Presumably, they did not spend enough time engaging with the system to enable a genuine effect of the visual feedback on the development of music aptitude. Future research needs to address the issue of time spent engaging with the system.

10.6. Conclusion

This study aimed at measuring the influence of technology-aided instruction on the developmental music aptitude. The results of this study did not reveal a significant difference between the control group and the treatment group. However, in this study it became clear that conducting research with educational technologies in an ecological setting demands for measurement methods that go beyond a product oriented approach in which a pre-test post-test design is used to test the effectiveness (amplicative impact) of an educational technology. Inserting such a technology in the classroom setting has an impact on many aspects of instruction, all of which might influence, among others elements of musical growth, the developmental music aptitude of the children. Researching these aspects is vital to investigate the transformative power of educational technologies.

Part 4: General Discussion and Conclusion

CHAPTER 11

General Discussion and conclusion

11.1. Overview

In this thesis we investigated the possible contribution of an interactive music system, the Music Paint Machine, to an embodied constructivist approach to instrumental music instruction. Our work was guided by the following research question:

> *How and to what degree can an interactive music system contribute to the development of an embodied understanding of music when learning how to play a musical instrument?*

This research question entails three key elements that constitute the objective, the goal and the condition of instrumental music teaching and learning as conceived in this thesis. These key elements are:

- *an embodied understanding of music*
- *learning to play a musical instrument*
- *an interactive music system*

We addressed these three key elements in the first three parts of this thesis, in which we presented a pedagogical, a technological and an empirical framework.

In PART 1 we developed the pedagogical framework. On the basis of three characteristics of “traditionalist” instrumental music instruction, namely a master-apprentice model, a primacy of the score and an alienation from the learners’ reality of daily life, we have shown that this approach influences the different components of instruction. These components are, according to Kennel (20020), the learner, the teacher, the interaction between them, and the musical material (Chapter 1). It was argued that, based on these characteristics, the traditionalist approach to music instruction leads to a learning environment that is prone to critique because of its consequences for the learner (Chapter 2). Among these consequences are, for example, a neglect of the learner’s autonomy and individual artistic voice or less musical sensitivity. As an alternative, we have proposed an embodied constructivist approach (Chapter 3). This approach creates a learning environment that is knowledge-, assessment-, learner- and community-centered (Bransford, 2000). The learner takes a central position and plays an active role in the acquisition of knowledge. In this approach, the body plays a prominent role. Acquiring knowledge and understanding are grounded in a corporeal engagement with music (Leman, 2007).

In PART 2 we developed the technological framework of this research. We argued that interactive music systems can contribute to an embodied constructivist approach to instrumental music instruction on the basis of two specific features, namely the use of visual feedback and the integration of body movement (Chapter 4). In this part we also presented the Music Paint Machine, the interactive music system that was designed during this research project (Chapter 5). This system was designed on the basis of a novel approach to monitoring, based on the creative use of visual feedback and on to the use of the unity of body and instrument as controller of the system.

In PART 3 we developed the empirical framework of this research. Based on the rationale that a valid scientific investigation must be based on the possible integration of the interactive system in a naturalistic educational setting, it was argued in favour of a research approach that is driven by pedagogy, connected to the field of practice and focused on the transformative impact of the technology (Chapter 6). Then we elaborated on the relationship between musician and musical instrument (Chapter 7). In our view, an optimal relationship between the two involves the incorporation of the instrument. Based on ecological philosophy, activity theory and the psychology of optimal experience, we investigated the processes that underlie such relationship. Furthermore, we argued that flow experience, skill-based playing and direct perception are the basic components of an embodied interaction with music. This theoretical investigation was to a large degree the basis for the empirical work. Next, we reported on two experiments. The first experiment was a user study that probed the participants' personal experience with the system and their evaluation of its didactic potential (Chapter 8). For this experiment a questionnaire was designed to probe the experience of presence while engaging with an interactive music system. In this way the measurement of presence was introduced in music research. Up until now, the concept of presence was briefly referred to in the literature on music research (e.g. Leman 2007). The results of this experiment suggested the system's potential to elicit a flow experience and the system's relevance for music instruction. The results also provided an empirical validation of the intrinsic relationship between flow and presence (Chapter 9). The second experiment was a longitudinal study in which children learned to play the clarineo with the instructional support of the Music Paint Machine (Chapter 10). In this study, good practices were developed and the amplicative impact (focus on outcomes) of the system was tested on the basis of a non-equivalent control groups design. We did not find a significant difference between the control and treatment groups with regard to the dependent variable (music aptitude). However, this study made clear that it is necessary to focus on the transformative impact (focus on processes) of technology.

11.2. General discussion

In this research, we developed a pedagogical, technological and empirical framework that enabled us to design, implement and evaluate the Music Paint Machine, an interactive music system for instrumental music instruction.

11.2.1. Pedagogical framework: An embodied constructivist approach

As an alternative to the so-called traditionalist approach, the combination of educational constructivism and the theory of embodied music cognition has provided a valuable approach to instrumental music instruction, and as such to the elaboration of the concept of embodied music cognition within an educational context. In this thesis important steps have been taken in bringing both theories together. The theory of embodied music cognition was used to elaborate on essential aspects of educational constructivism, such as the construction of knowledge and active role of the learner. We emphasized the importance of developing a motile body and an optimal relationship with the musical instrument in order to enable the construction of embodied knowledge and understanding. We also argued in favour of a multimodal approach in order to appeal to the multimodal nature of musical experience. Acknowledging these aspects of an embodied approach to instrumental music teaching and learning leads to the design of activities that constitute a powerful learning environment. As such, the learner is stimulated to take control over the learning process and actively construct knowledge and develop understanding, as opposed to the more passive role within the master-apprentice model. However, we do believe that the value of the master-apprentice model is still open to discussion. For example, Gardner favours a master-apprentice model when teaching highly gifted students (Gardner, 1985). He also asserts that this model helps students to appreciate and assimilate the special nature of artistic learning and artistic knowledge (Gardner, 1990). Another example of the way the master-apprentice model can be valued is Bandura's social learning theory, which posits that most human behaviour is learned observationally through modelling (Bandura, 1997). A last example is the coupling of the master-apprentice model to the zone of proximal development. When working with experts (teachers), novices develop a shared understanding of important processes and integrate this with their current understandings (Schunk, 1991). In this way they can cross the zone of proximal development. These examples indicate that multiple interpretations of the master-apprentice model are possible. Arguably, what seems at stake is not so much the master-apprentice model as such but rather the way this model is shaped. What seems important is that the "master" possesses the necessary pedagogical content knowledge (PCK) to adopt an approach that fosters an embodied understanding. We believe that knowledge about the constructivist learning and about the embodied nature of music cognition are necessary components of the teacher's PCK that allow to go beyond a schoolish approach to the master-apprentice model.

Another point that is open to discussion is the role of score. In this thesis we have shown that exploration, experimentation and improvisation are essential didactic practices within an embodied constructivist approach (see Chapter 3). While these practices are most often linked to playing without a written score, they can also be used when starting from a written score. A large part of, for example, the Western classical music, has an underdetermined character (Bazzana, 1997) and, accordingly, a written score entails a "constant stock of possibilities" (Benson, 2003). When learners are stimulated to explore and to experiment with these possibilities, they can also construct knowledge on the basis of their personal – embodied – experience of the music (e.g. Hultberg, 2000). Furthermore, it is possible to improvise with the musical building blocks of an existing score. For these reason, one could argue that a score-based approach can possibly be an embodied constructivist approach. We believe that more research is needed to address these points of discussion.

11.2.2. Technological framework: A novel approach through the creative use of body, sound and visuals

In this thesis we developed a technological framework for the design of the Music Paint Machine. We believe that we have presented a novel approach to the design and use of interactive music systems within the context of instrumental music instruction. The Music Paint Machine differs from many existing systems with regard to the use of visual feedback, the role of body movements and the different possible practices. As such it can complement these systems and contribute to the ongoing developments in the domain of music educational technologies.

Creative visual feedback

Many existing systems provide visual feedback to the music student (see section 4.1. for an overview). The Music Paint Machine also provides visual feedback on what and how the music student is playing but this information is embedded in a creative visual display, the "painting". This conception of visual feedback aims at the development of a playfulness with musical parameters. We believe that this is an important novelty in our approach. In our opinion, systems that focus on monitoring sound and movement in function of "correct" ways of playing (e.g. by comparing monitored movements to a model) can support or even reinforce the characteristics of the traditionalist approach to instrumental music instruction. In contrast the Music Paint Machine seeks, instead of merely providing information (knowledge of results), to invite learners to explore and experiment with music, with the body and with the visual output. The participants of the user study have acknowledged the didactic potential of this approach. A majority of the participants stated that the visual feedback stimulates to pay more attention to the musical parameters and to make more use of them. But despite the potential of visual feedback, caution is needed because visual feedback can, depending on the way it is implemented, have a degrading effect on learning. Results of the experiment on the user experience suggested that the visual feedback of the Music Paint Machine does not interfere with playing. Of course, with regard to the didactic potential of the system, results were based on the participants' subjective evaluation, not on objective measurement. However, results from the flow and presence questionnaire suggested that the system has the potential to elicit an optimal experience. This validates the participants' evaluation of the feedback as not disturbing.

Further research is needed to clarify the effect of feedback on learning and to investigate the effect of different kinds of visual feedback. Brandmeyer and colleagues (2011) compared low-level visual feedback (based on raw features of the music) to high-level (categorical) visual feedback (based on Bayesian analysis). The high-level feedback was found to be disruptive to timing but helped students better to imitate the teacher's model. Wilson and colleagues (Wilson, et al., 2008) compared the effectiveness of different kinds of feedback on singing accuracy. The first kind of visual feedback showed a linear pitch trace on a grid (based on Sing&See™, see section 4.1), the second kind of feedback show a keyboard. Both kinds of feedback led to increased pitch accuracy while the control group did not improve. Both studies are very valuable and contribute to our understanding of the effect of visual feedback. Howevre, we believe that the kinds of feedback that are compared could be improved, possible by appealing to Bruner's categorization of knowledge representation (enactive, iconic, symbolic).

Bodily freedom

A growing number of interactive music systems monitor the player's movements. The Music Paint Machine also monitors the player's movements but goes beyond merely providing learners with visual feedback on their movements (knowledge of performance). It invites to creatively use the body while playing a musical instrument and integrates movements that differ from the habitual gestures (Jensenius, et al., 2010). It is assumed that the combination of playing music and executing extra movements creates a bodily freedom ("motile" body), whereas the mere monitoring of movements possibly constrains movements ("docile" body). Results from the user study indicated that the system indeed stimulates to experiment with the body while playing an instrument. In our opinion, the free use of the body can contribute to the establishment of an optimal relationship with the musical instrument. We also believe that the bodily freedom can contribute to musical expressiveness. Expressiveness has been linked to bodily freedom (Davidson & Correia, 2001, 2002). However, at this point, this assumption is still rather speculative. Longitudinal empirical research is needed to address the possible link between bodily freedom and musical expressiveness. This research needs to integrate the quantitative measurement of movements in combination with the qualitative measurement of the subjective experience. The development of the presence questionnaire can contribute to the quantitative measurement (see Chapter 9). The degree to which presence occurs informs on the degree to which the interaction with a technology (interactive music system, musical instrument) affects the body. That is, the quality of experience is determined by the quality of bodily engagement. The results of the user study indicated that users experienced less presence when the movements to control the system were experienced as disturbing musical expression.

Diversity of practices

A final feature of the Music Paint Machine that differs from most other educational technologies is the diversity of the uses it supports on the basis of the system's customizability. We believe this is one of the strengths of the system. It allows customizing the system to different learning contexts and differentiating between learners. This became clear during the longitudinal study (see Chapter 10). Whatever content was prepared for a lesson (e.g. on rhythm, new notes, dynamics, expression), different practices with the system could be developed to support instruction. However, this feature at the same time challenges the teacher, who is obliged – at least at this moment – to design proper levels in function of the learning content. In this way the system magnifies the – as often perceived by teachers – already protean nature of the computer (Mishra & Koehler, 2003; Papert, 1980). This also became clear in the longitudinal study. Preparing lessons with the system was a time consuming activity. Accordingly, it might present too big a challenge to many teachers and as such, in contrast with the aim of the system, hinder its acceptance by other teachers (Koehler & Mishra, 2009). Future developments have to consider this and focus on the making of different modules that provide teachers with straightforward uses. Levels can be made on the experience of teaching with the system that is gained throughout the longitudinal study.

Development of the system

A recurrent issue in the development of the Music Paint Machine was the sometimes-difficult relationship between pedagogical-didactical aims, the research aims, and the user preferences. One example is the choice of a motion sensor. It is clear that the sensing device must be unobtrusive in order to optimize the user experience. Wireless motion tracking therefore is a premise for the choice of sensors. The search for a wireless motion tracking system led to the use of an inertial motion sensor that integrated a magnetometer, a gyroscope and an accelerometer (see section 5.3.1.). But while this sensor delivered very precise and reliable measurement data (research aim), its usability was not sufficient. The local magnetic field of the sensor and, consequently, the orientation estimation was easily disturbed by the presence of ferromagnetic materials. Furthermore, attaching and changing the sensor from one person to another was not user-friendly. The sensor was attached to suspenders. For women or girls this caused a problem when they were wearing a dress. Sometimes the suspenders loosened because of the movements. Also changing the suspenders from one person to another was not very practical. To optimize the user friendliness and unobtrusiveness of the system in view of the instructional setting of the longitudinal study, it was chosen to use the Kinect® sensor. But while this sensor has important functional advantages, the measurement data are not accurate and therefore not usable as scientific data. In view of combining qualitative and quantitative measurements with regard to the use of the body when learning how to play an instrument, this was a major disadvantage.

Another example is the shape of the coloured pressure-sensing mat. Based on envisioned didactic practices (e.g. stepping exercises, developing bodily motility), it was chosen to use a circular configuration of the colours. However, participants from the first experiment (see Chapter 8) regularly expressed a preference for a keyboard-like configuration of the colours because then they could more easily see all the colours without the need to turn away from the screen. A first step to tackle this discrepancy between user experience and didactic aims was the introduction of a visual representation of the colour mat on the screen (as suggested by several participants). The next step, currently ongoing, is the development of a flexible pressure sensing system, allowing for different configurations.

A final example concerns the variety of possible practices with the Music Paint Machine. From a pedagogical point of view, this is an important asset of the system. It allows designing custom levels in function of specific learning content. It also allows adapting the didactic practices to the particular needs of individual learners. However, from a research point of view, the protean nature of the system possibly impedes the immediate use of straightforward controlled experiments. It requires, prior to conducting such experiments, the development of good practices. The longitudinal study that was conducted (see Chapter 10) aimed at establishing such good practices. It enabled to find out how the system can be used in function of different didactic goals. Future work with the Music Paint Machine includes controlled experiments on the basis of the practices that were developed in this longitudinal study.

11.2.1. Empirical framework: A pedagogically grounded and practice-based approach.

In this thesis we have described the establishment of an empirical framework to design and test the Music Paint Machine. Three aims guided the research, namely being driven by pedagogy, being connected to the field of practice and focusing on a transformative impact.

Driven by pedagogy

We believe that, due to the researcher's experience as a teacher in formal music education, this research has been pedagogy driven from the very start. Inspired by the years of daily teaching and performing, a strong desire emerged to deepen pedagogical insights and to develop novel didactical practices for instrumental music teaching and learning. This thesis is motivated by this desire. Developing the Music Paint Machine and the empirical framework was considered as a way to gain these insights and to develop these practices, based on scientific investigation. Accordingly, the possibilities of new technologies have merely been a source of inspiration, not the incentive of the research.

Next to this practice-based incentive, the research was driven by the idea that the design and implementation of an interactive music system needs to be embedded in a firm pedagogical framework. It was found that the combination of educational constructivism and the theory of embodied music cognition provide such a framework. First steps have been taken in bring both theories together but further conceptual work is necessary.

Finally, we believe that combining the theories of educational constructivism and embodied music cognition provides an excellent basis for the design of educational experiments that have a practical relevance. The longitudinal experiment is an example of this pedagogy driven approach. Instruction was tailored to the

Connected to the field of practice

A major concern throughout the research has been to stay connected to the field instead of becoming an "outsider". Mainly by giving lectures during pedagogical workshop, this research was presented to teachers in order to discuss the relevance of the research. This dialogue with colleagues is quite important because it stimulates the debate on the gap between research and practice and makes research more available to the practice community (e.g. Broekkamp & van Hout-Wolters, 2007; Vanderlinde & Van Braak, 2010).

Next to the dialogue with teachers, the connectedness with the field is a matter of (re)defining the role of teachers within educational research. As shown in chapter 4 (section 4.1) and elaborated on in chapter 6, the role of teachers in education technology research is too limited. Often, few teachers are solicited to participate in studies with the technology. We are aware of the difficulty of finding teachers to participate for reasons related to the required effort, to technology acceptance or to the time consuming nature of the participation (see also: Cox, et al., 2003). This certainly has an effect on the number of teachers that participate. But in our opinion the deeper cause lies in the way teachers are addressed. In chapter 6 we argued that too often teachers are seen as end-user or mere participants in the experiment. Seldom they are co-constructors of research.

We believe that our research is a step in the right direction, mainly because of the concern with the practical relevance of the system, which is an important aspect of the connectedness to the field. Based on the user study (Chapter 8), teachers' opinion on the didactic potential was probed in order to gain understanding of this practical relevance. This user-oriented approach is common to investigate how people experience a technology. The longitudinal study did not involve other teachers but this study aimed at bringing research to a naturalistic setting and as such gained practical relevance (e.g. Everton, Galton, & Pell, 2000). The pilot study (see Chapter 6) involved other teachers and aimed at understanding the process of technology integration. Following the teachers through observation, questionnaires and focus groups was a way of involving the teachers as vital interlocutors in the development of the Music Paint Machine and the didactic practices with the system.

However, we also believe that it is necessary to go a step further and develop an approach in which teachers are co-researchers. Valuing the teachers as partners in producing research and in identifying problems that merit to be investigated, leads to improving the value and relevance of the educational technology through the combined knowledge of teachers and researchers (Amiel & Reeves, 2008).

A possible approach for future studies with music educational technologies is the "learning by design" approach as adopted by Mishra and Koehler (Koehler & Mishra, 2005a, 2005b). In this approach, teachers work together in small groups to develop technological solutions to authentic pedagogical problems. In collaboration with researchers, this approach constitutes a process of weaving together components of technology, content, pedagogy and scientific method. An important advantage of this approach is the knowledge base teachers develop throughout the research process. This knowledge basis is referred to as TPACK, or: Technological Pedagogical Content Knowledge (Koehler & Mishra, 2009). This knowledge reflects an understanding that emerges from interactions among content, pedagogical, and technological knowledge. The basic idea is that, in order to effectively use technological applications in the classroom, teachers need to integrate three forms of knowledge (content, pedagogical and technological knowledge). According to this framework, technology integration is not the mere adding of technology (as some kind of independent variable) to the existing teaching and content domain.

When researchers and teachers establish together an experimental framework, their combined knowledge provides the framework with a solid knowledge base, allowing for an integrative empirical framework, where educational technology research is at the intersection of content, pedagogical, technological and research knowledge (see Figure 11.1).

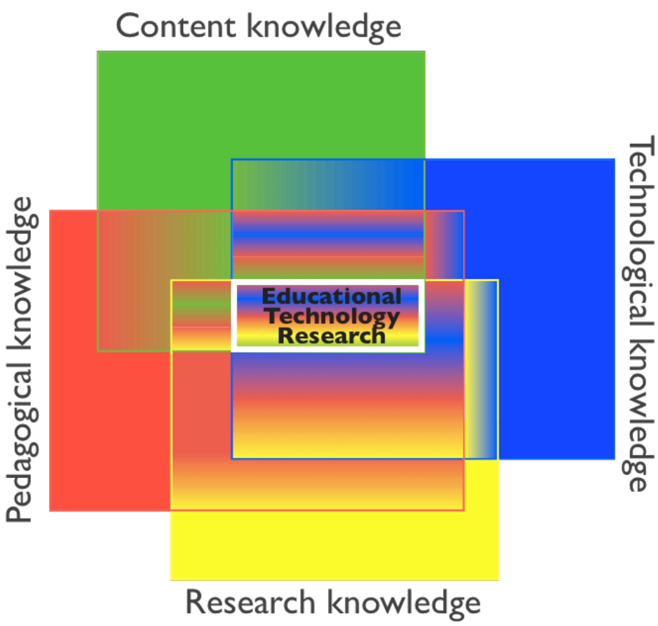


Figure 11.1. Educational Technology Research needs to be based on the combined knowledge of teachers and researchers

Focused on technology's transformative impact

Next to being driven by pedagogy and being connected to the field of educational practice, the third aim of the empirical framework emerged throughout the research, namely a focus on the transformative impact of technology.

While in the beginning this research adhered to the instrumentalist approach, characterized by the purpose of empirically validating the theorized efficiency of the Music Paint Machine, gradually it became clear that it is necessary to focus on the transformative impact of this interactive music system.

Experiencing week after week this transformative impact, the researcher realized, from his privileged position as researcher-teacher (e.g. Campbell, 2011), that using such a technology affects the different components of instruction as described in chapter 1. Using the Music Paint Machine influenced the teacher-learner interaction (e.g. the proxemics of teaching), the learners (e.g. jumping on the mat, waiting turn, running in front of Kinect®), and the teacher (e.g. worries on timing, interacting with the computer). Currently these findings are based on the researcher-teacher's subjective personal inspection (Gould, 1995; Woodside, 2004). Evidently we are aware of the fact that due to the reconstructive nature of long-term memory and memory's distorted sampling of the past, these teacher-researcher's retrospective considerations might be biased. Therefore, future work involves a microanalysis of the video footage of the lessons based on a systematic observation. A coding system is currently being developed on the basis of the work of different scholars (Colprit, 2000; Custodero, 2005; Duke, 1999a, 1999b; Duke, et al., 1998; Flanders, 1970; Heikinheimo, 2009; Karlsson & Juslin, 2008; Rostvall & West, 2003, 2008; Zhukov, 2004). Future studies would benefit from an approach in which a quasi-experimental design is combined with methods from action research such as keeping a teacher diary and interviewing the children and their parents.

11.3. Limitations of the study

This research has several limitations. A first limitation is the number of participants. In total sixty-three students and seventeen teachers participated.

A second limitation concerns the technology. In the process of the project it became clear that the design of an interactive music system that serves the purpose of being both a research tool and an educational tool is a process with several pitfalls that are related to essential elements of the research. Among these pitfalls are the usability of the system as a possible confounding factor, the balance between usability and accurate scientific measurement when choosing the appropriate sensing devices, or the continual necessity to update the software. It is clear that these elements have an impact on how the system is used and consequently on how it is experienced and evaluated.

A third limitation concerns the measurement methods and tools. Testing the instructional effectiveness of a system and measuring the impact of an interactive musical instrument demands a long-term project. For example, while empirical investigations might not reveal an immediate effect, it is possible that using an interactive music system in the initial stages of learning how to play an instrument has an impact that shows only later on in the learning process. Furthermore, current measurement tools that enable to investigate the impact of engaging with interactive music systems to learn how to play music are still in its infancy and thereby somehow constrain empirical research. Further advancements are needed, especially with regard to the development of measurement tools for young children.

11.4. Conclusions and future work

11.4.1. Contributions

We believe that our research has made a valuable contribution to the study of musical experience while engaging with an interactive music system. Our main contributions are:

- *the coupling of constructivism and embodied music cognition.* This led to a general pedagogical framework in which principles of constructivism and embodied music cognition are used to develop an approach that fully takes into account the role of the human body as mediator between knowledge and environment.
- *the elaboration of a contextual framework for the investigation of the relationship between musician and musical instrument.* This framework provides a conceptual basis for the establishment of an empirical framework that investigates this relationship. Interactive music systems that consider this conceptual framework, such as the Music Paint Machine, might be used to conduct controlled experiments in order to investigate the relationship between musician and musical instrument.
- *the elaboration of the relationship of flow and presence within the theory of embodied music cognition.* Bringing the construct of presence in the domain of interactive music systems and, especially, using to concept to design measurement tools such as our in-house designed presence questionnaire, contributes to a user-oriented approach and to the expanding palette of

methodologies in music research. Up until now, the concept of presence has only been briefly referred to in the musicological research.

- *the development of an empirical framework for the research-based design of an interactive music system and for the study of the potential role of such a system in instrumental music teaching and learning.* Although the framework needs further development, important steps have been taken to establish a pedagogically grounded and practice-based research framework.
- *the development of a technology-enhanced music instrument learning system, based on interactive technology.* This system is still in a proto-type phase but the particular nature of the system (the unity of body and instrument as controller of the system, the creative use of body movement and visual feedback) provides an excellent opportunity to study the role of visual feedback, the use of body movements and their integration when learning how to play an instrument.
- *an embodied approach to instrumental music learning.* The ideas in this thesis contain the germ of a new approach to instrumental music teaching and learning that integrates a particular – creative – use of the body.

11.4.2. Future work

This thesis has laid out a basis for possible future pedagogical, technological and empirical research in the domain of education technologies.

- *Pedagogical framework:*

  We believe it is necessary to further elaborate the combination of the embodied music cognition paradigm and educational constructivism. A possible way to proceed is to develop an in-depth account of the emergence and functionality of schemas when learning how to play an instrument.

  The ideas with regard to the use of bodily motility when learning to play an instrument needs to be further developed. While technology can contribute to this approach by providing digital learning environments that stimulate a creative use of the body, we believe that it is also possible to develop similar didactic practices without technology.

- *Technological framework:*

  We envision the further development of the hard- and software components of the Music Paint Machine. The future coloured pressure sensing mat will be designed to allow for a flexible configuration (e.g. circle, half-round, line). Additional perspectives on the painting (e.g. top view, side view) will be integrated in order to visualize different aspects of the playing against time (e.g. amount of movement, use of pitch). Furthermore, ready-to-use software levels will be developed to support specific didactic practices.

  An important part of the future development of the Music Paint Machine is the integration of a motion tracking sensor that is unobtrusive like the Kinect® but also provides accurate scientific data.

- *Empirical framework:*

  We believe that the reflections on instrumental didactics and the findings of the experiments can inspire the formulation of research questions with regard to technology-enhanced music instruction. As such they can lead to further empirical investigations. For example, brain research could provide interesting insight with regard to the impact of repeatedly using multimodal interactive music systems on the perception of music. Another example of possible future research concerns an embodied approach to the score.

  Concerning the empirical investigations, it is necessary to further refine the methodologies that were adopted in this research. For example, measurement tools such as the presence questionnaire and the design of a naturalistic setup that allows unobtrusive measurement can be improved and further developed.

  A challenge for further work is to involve more teachers and to do more empirical research in a naturalistic setting.

  Finally, the Music Paint Machine can be used in experiments that address fundamental research topics such as the coupling of action and perception, the coupling of bodily freedom and musical expressiveness or cognitive and motor load in music performance.

11.4.3. Conclusion

The research presented in this thesis has contributed to the domain of music educational technology research by developing a pedagogical, a technological and an empirical framework for the pedagogically grounded and practice-based design of an interactive music system. In the course of this research we have developed the Music Paint Machine, an innovative interactive music system that allows a musician to make a digital painting by playing a (traditional) musical instrument and by moving the body. Based on a combination of educational constructivism and the theory of embodied music cognition and based on an in-depth account of the relationship between musician and musical instrument, we have proposed a novel approach to the integrative use of movement, sound and visual feedback. The system has been evaluated on the basis of a user study and a longitudinal case study. The results are promising but further research is needed that focuses on the transformative impact of music educational technologies such as interactive music systems.

APPENDICES

Appendix A
In house designed presence questionnaire

Witmer & Singer PQ	Nijs et al Presence Questionnaire	label
1. How much were you able to control events?	1. I felt like I could do what I wanted	control
2. How responsive was the environment to actions that you initiated or performed?	2. The system responds well to what I do	systems responsiveness
3. How natural did your interactions with the environment seem?	3. It felt natural to use the system	system naturalness
4. How much did the visual aspects of the environment involve you?”	4. While performing, I paid attention to the screen	attention to screen
5. How much did the auditory aspects of the environment involve you	5. While performing, I paid attention to the music	attention to music
6. How natural was the mechanism which controlled movement through the environment?	6. The mapping between my actions and the effect they generated, felt natural *(e.g. play loud = thick line, play soft = thin line, pitch to vertical position on the screen)*	natural mapping
7. How compelling was your sense of objects moving through space?		
8. How much did your experiences in the virtual environment seem consistent with your real world experiences?	7. “The things I had to do (move feet, turn torso) deviate too much from the normal way of performing on my instrument and playing music”	unusual actions
9. Were you able to anticipate what would happen next in response to the actions that you performed?	8. “I could predict the effect of my actions”	anticipation
10. How completely were you able to actively survey or search the environment using vision?		
11. How well could you identify sounds?		
12. How well could you localize sounds?		
13. How well could you actively survey or search the virtual environment using touch?		
14. How compelling was your sense of moving around inside the virtual environment?		
15. How closely were you able to examine objects?		

16. How well could you examine objects from multiple viewpoints?		
17. How well could you move or manipulate objects in the virtual environment?		
18. How involved were you in the virtual environment experience?		
19. How much delay did you experience between your actions and expected outcomes?		
20. How quickly did you adjust to the virtual environment experience?		
21. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	9. I succeeded to draw in different ways *(thin &* thick lines*, long & short lines, different colours, change drawing direction, ...)*	varied drawing
22. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?		
23. How much did the control devices interfere with the performance of assigned tasks or with other activities?		
24. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?	10. While performing, I paid attention to my movements	attention to movement
	11. While performing, I paid attention to my musical instrument	attention to instrument
	12. While performing, I paid attention to the pressure mat	attention to mat
	13. While performing, I paid attention to the movement sensor	attention to sensor
25. How completely were your senses engaged in this experience?		
26. To what extent did events occurring outside the virtual environment distract from your experience in the virtual environment?	14. While performing, I paid attention to what happened around me	attention to surroundings

27. Overall, how much did you focus on using the display and control devices instead of the virtual experience and experimental tasks?	15. I was able to concentrate on the task (make a painting) without being preoccupied with the mechanisms that enable the making of a painting *(pressure mat, musical instrument,* movement sensor, computer*)*	non-mediation
	16. Using this system requires a great mental effort (*I need to think a lot when using it*)	cognitive load
28. Were you involved in the experimental task to the extent that you lost track of time?		
29. How easy was it to identify objects through physical interaction, like touching an object, walking over a surface, or bumping into a wall or object?		
30. Were there moments during the virtual environment experience when you felt completely focused on the task or environment?		
31. How easily did you adjust to the control devices used to interact with the virtual environment?	17. I needed some time to get used to the system before I understood how to use it	get used
	18. The system requires a long learning phase before being able to use it spontaneously	long learning phase
32. Was the information provided through different senses in the virtual environment (e.g., vision, hearing, touch) consistent?	19. This system stimulates different senses	multimodality
	20. The system stimulates me to be creative with musical parameters (loud-soft, short-long, articulation, ...)	creativity

Appendix B

Home Musical Environment Questionnaire (HME)

Musical Home Environment

Dear parents,

With this questionnaire, we try to determine the place which music occupies in the home environment of your child.
This questionnaire has 4 parts. The first 3 parts probe the way in which music is engaged with (at home) by:

(1) you
(2) your child
(3) possible brother(s) or sister(s) of your child

A final part probes:

(4) the presence of musical material at home.

We kindly invite you to complete this questionnaire separately from each other, that is without consulting each other.
If one of the parents is not able to complete this questionnaire, it can be completed by another adult that knows your child well enough to answer these questions (e.g. grandfather or grandmother).

We would like to ask you to consider the following when answering the questions:

- Please, try to answer the questions as honestly and accurately as you can. Your answers will be treated in the strictest confidence and will be stored securely. They will only be used by the researcher.
- There are no right or wrong answers. We are interested in your opinion.
- Please, try to answer each question, even if you doubt.

For further questions and information, please contact Luc Nijs (0498/26.43.02)

Thank you very much for completing this questionnaire with the necessary seriousness.

Luc Nijs

1) **Name & first name:** ....

2) **Gender**

- ❍ female
- ❍ male

3) **Age:** ....

4) **What is the highest level of education you have completed?**

Please select the answer that applies most to you

- ❍ primary school
- ❍ secondary school
- ❍ bachelor
- ❍ master
- ❍ PhD
- ❍ other: ....

5) **What is your current position?** ....

6) **Do you play a musical instrument?**

- ❍ no *(go to question)*
- ❍ yes *(go to question 7)*

7) **For how many years do you play your instrument?**

Please select the answer that applies most to you

- ❍ 1 to 3 years
- ❍ 4 to 6 years
- ❍ 7 to 9 years
- ❍ more than 10 years

8) **What type of musical instrument instruction did you receive?**

You can select more than one answer

- ❑ none, I'm autodidact
- ❑ private instrument lessons
- ❑ non-formal instrument lessons
- ❑ formal music education – classical
- ❑ formal music education – jazz/pop
- ❑ music secondary school – classical
- ❑ music secondary school – jazz/pop
- ❑ royal conservatory/university - classical
- ❑ royal conservatory/university – jazz/pop
- ❑ other (*please specify*): ....

9) Are you still following instrument lessons?

- o no *(go to question 11)*
- o yes *(go to question 10)*

10) Please specify what type of lessons: ....

11) Do you play in an orchestra/ensemble?

- ❍ no *(go to question 13)*
- ❍ yes *(go to question 12)*

12) Which orchestra/ensemble? ....

13) How often do you play your instrument in the presence of your child?

Please select the answer that applies most to you

- ❍ every day
- ❍ a few times a week
- ❍ once a week
- ❍ less than once a week
- ❍ never

14) Do you ever sing?

- ❍ no *(go to question 20)*
- ❍ yes *(go to question 15)*

15) How often do you sing?

Please select the answer that applies most to you

- ❍ every day
- ❍ a few times a week
- ❍ once a week
- ❍ less than once a week
- ❍ never

16) In what condition do you sing?

You can select more than one answer

- ❑ on my own
- ❑ in a choir
- ❑ in a small ensemble (e.g. rock group, jazz ensemble)
- ❑ other (*please specify*): ....

17) Do you ever sing with your child?

- ❍ no *(go to question 20)*
- ❍ yes *(go to question 18)*

18) How often do you sing with your child?

Please select the answer that applies most to you

- ❍ several times a day
- ❍ once a day
- ❍ a few times a week
- ❍ once a week
- ❍ never

19) Which songs do you sing together?

You can select more than one answer

- ❑ songs from school
- ❑ traditional children's songs (e.g. "Row row row your boat")
- ❑ studio 100 children's songs (e.g. Plop, K3, Mega Mindy...)
- ❑ Ketnet songs (e.g. "Junior Eurosong", ...)
- ❑ popular music
- ❑ songs from cartoons (e.g.. Disney, Bob de Bouwer, ...)
- ❑ self invented songs
- ❑ existing melodies with self invented lyrics
- ❑ other (*please specify*): ....

20) Do you ever dance?

- ❍ no *(go to question 25)*
- ❍ yes *(go to question 21)*

21) How often do you dance?

Please select the answer that applies most to you

- ❍ every day
- ❍ a few times a week
- ❍ once a week
- ❍ less than once a week
- ❍ never

22) Where do you dance?

You can select more than one answer

- ❑ at home
- ❑ in a dance club
- ❑ in a disco or at a party
- ❑ other (*please specify*): ....

23) Do you ever dance with your child?

- ❍ no *(go to question 25)*
- ❍ yes *(go to question 24)*

24) How often do you dance with your child?

Please select the answer that applies most to you

- ❍ several times a day
- ❍ once a day
- ❍ a few times a week
- ❍ once a week
- ❍ never

25) On average, how much time per day do you spend listening to music?

Please select the answer that applies most to you

- ❍ more than 2 hours a day
- ❍ 1 or 2 hours a day
- ❍ 30 minutes or 1 hour a day
- ❍ less than 30 minutes a day
- ❍ never *(go to question 30)*

26) How often do you listen to the following musical styles?

Per item (in the left column), select the answer that applies most to you.

	never	rarely	occasionally	regularly	very often
pop/rock	❍	❍	❍	❍	❍
jazz/blues	❍	❍	❍	❍	❍
ethnic/world music	❍	❍	❍	❍	❍
folk	❍	❍	❍	❍	❍
rap	❍	❍	❍	❍	❍
electronic music	❍	❍	❍	❍	❍
classical music	❍	❍	❍	❍	❍
other *(see question27)*	❍	❍	❍	❍	❍

27) Specify “other” (if applicable): ....

28) When do you listen to music?

Per item (in the left column), select the answer that applies most to you.

	never	rarely	occasionally	regularly	very often
before going to work	❍	❍	❍	❍	❍
on the way to/from work	❍	❍	❍	❍	❍
during the break at work	❍	❍	❍	❍	❍
with meals	❍	❍	❍	❍	❍
while working	❍	❍	❍	❍	❍
in leisure time	❍	❍	❍	❍	❍

29) How often do you go to concerts/music performances?

Please select the answer that applies most to you

❍ weekly
❍ at least once a month
❍ a few times a year
❍ once a year or less
❍ never

30) How often do you go to concerts/music performances <u>together with your child</u>?

Please select the answer that applies most to you

❍ weekly
❍ at least once a month
❍ a few times a year
❍ once a year or less
❍ never

31) Does your child have a brother or sister that plays a musical instrument?

❍ no *(go to question 37)*
❍ yes

32) Number of brothers that play a musical instrument? ....

33) Number of sisters that play a musical instrument? ....

34) How often does your child hear her brother(s) or sister(s) play their instrument?

Please select the answer that applies most to you

- ❍ every day
- ❍ a few times a week
- ❍ once a week or less
- ❍ never

35) Does your child ever make music together with its brother(s) or sister(s)? (E.g. brother(s) or sister(s) play their instrument while your child sings or drums along ...)

- ❍ no *(go to question 37)*
- ❍ yes

36) How often do they make music together?

Please select the answer that applies most to you

- ❍ every day
- ❍ a few times a week
- ❍ once a week or less
- ❍ never

37) Which musical material do you have at home to be used by your child?

- ❑ cd-player and cd's / radio
- ❑ TV
- ❑ small percussion (e.g. little drum, triangle, djembee, ...)
- ❑ wind instruments (e.g. recorder, ocarina, ...)
- ❑ piano
- ❑ guitar
- ❑ song books
- ❑ computer games (e.g. Nintendo Rhythm Paradise, Wii music, Guitar Hero)
- ❑ other *(please specify)*: ....

38) To what extend do you agree or disagree with the following statements?

Per item (in the left column), select the answer that applies most to you.

	completely disagree	somehow disagree	neither agree nor disagree	somehow agree	completely agree
My child will need my help when practicing	❍	❍	❍	❍	❍
I'm not sure whether my child will practice enough on his/her own	❍	❍	❍	❍	❍
I can help my child practicing	❍	❍	❍	❍	❍

39) Name & first name of your child: ....

40) Gender of your child

- ❍ girl
- ❍ boy

41) Age of your child: ....

42) Number of brothers? *(Please, also specify age):* ....

43) Number of sisters? *(Please, also specify age):* ....

44) On average, how much time per day does your child spend listening to music?

Please select the answer that applies most to your child

- ❍ more than 2 hours a day
- ❍ 1 a 2 hours a day
- ❍ 30 minutes a 1 hour a day
- ❍ less than 30 minutes a day
- ❍ never

45) How often does your child listen to the following musical styles?

Per item (in the left column), select the answer that applies most to you.

	never	rarely	occasionally	regularly	very often	I don't know
Studio 100 songs (e.g. K3, Plop, ...)	❍	❍	❍	❍	❍	❍
traditional children's songs (e.g. "row row row your boat")	❍	❍	❍	❍	❍	❍
pop/rock	❍	❍	❍	❍	❍	❍
jazz/blues	❍	❍	❍	❍	❍	❍
ethnic/world music	❍	❍	❍	❍	❍	❍
folk	❍	❍	❍	❍	❍	❍
rap	❍	❍	❍	❍	❍	❍
electronic music	❍	❍	❍	❍	❍	❍
classical music	❍	❍	❍	❍	❍	❍
other *(see question 27)*	❍	❍	❍	❍	❍	❍

46) Specify "other" *(if applicable):* ....

47) How often does your child go to a concert/music performance?

Please select the answer that applies most to you

- ❍ weekly
- ❍ a few times a month
- ❍ a few times a year
- ❍ once a year or less
- ❍ never

48) How often does your child participate in a concert/music performance? (e.g. at school, in a youth movement, ...)

Please select the answer that applies most to you

- ❍ weekly
- ❍ a few times a month
- ❍ a few times a year
- ❍ once a year or less
- ❍ never

49) Can you specify in which situation? ....

50) How often does your child sing in the following conditions?

Per item (in the left column), select the answer that applies most to you.

	never	rarely	occasionally	regularly	very often	I don't know
alone and without media (tv, radio, cd, pc)	❍	❍	❍	❍	❍	❍
alone and with media	❍	❍	❍	❍	❍	❍
with a parent and without media (TV, radio, cd, pc)	❍	❍	❍	❍	❍	❍
with a parent and with media	❍	❍	❍	❍	❍	❍
with brother(s), sister(s) or peers and without media(TV, radio, cd, pc)	❍	❍	❍	❍	❍	❍
with brother(s), sister(s) or peers and with media	❍	❍	❍	❍	❍	❍

51) How often does your child dance at HOME in the following situations?

Per item (in the left column), select the answer that applies most to you.

	never	rarely	occasionally	regularly	very often	I don't know
alone and without media (tv, radio, cd, pc)	❍	❍	❍	❍	❍	❍
alone and with media	❍	❍	❍	❍	❍	❍
with a parent and without media (TV, radio, cd, pc)	❍	❍	❍	❍	❍	❍
with a parent and with media	❍	❍	❍	❍	❍	❍
with brother(s), sister(s) or peers and without media(TV, radio, cd, pc)	❍	❍	❍	❍	❍	❍
with brother(s), sister(s) or peers and with media	❍	❍	❍	❍	❍	❍

52) How often does your child participate in a dance performance? (e.g. at school, in the youth movement, with peers for parents & family ...)

Please select the answer that applies most to you

- ❍ weekly
- ❍ a few times a month
- ❍ a few times a year
- ❍ once a year or less
- ❍ never

53) can you specify in which situations? ....

Appendix C

Materials of the longitudinal study

" Play from your heart. Not like a tamed bird "
(Pablo Casals)

… / … / 12

POINTS OF ATTENTION

1. ……..…………..……...……. 2. ………..…...…………………

3. ……..…………….………..… 4. …….……....…………………

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

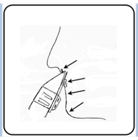
MON	Ma or Pa
TUE	Ma or Pa
WED	Ma or Pa
THU	Ma or Pa
FRI	Ma or Pa
SAT	Ma or Pa
SUN	Ma or Pa

REMARKS

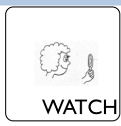
………...
………...
…………………………………………………………………………………

The student’s homework diary with a section on practice time and help, to be completed by the parents.

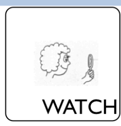
HOMETASKS LESSON 4

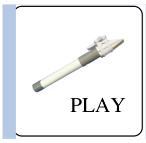


EMBOUCHURE (on g, e & d)

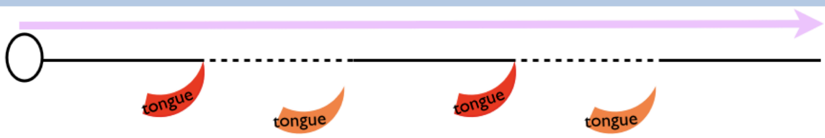


TONGUING EXERCICES (all)

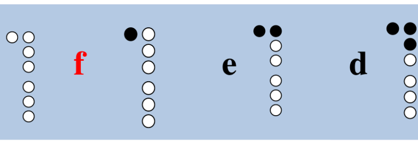


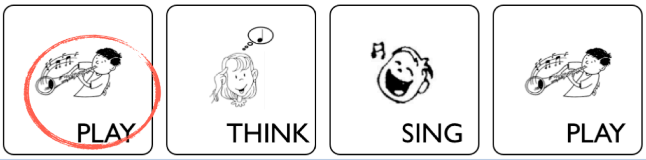


“TELEPHONE” on g, e & d



FIRST NOTES: g f e d





TWO-NOTES-EXERCICES with g, e, d & f

g – f – g – f – g – f – g – f ….

g – e – g – e – g – e – g – e …

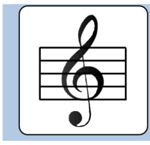
e – f – e – f – e – f – e – f – e …

e – d – e – d – e – d – e – d – e …

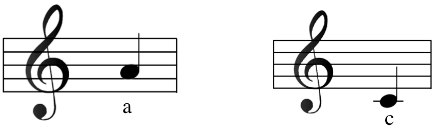
KEEP BLOWING WHILE MOVING THE FINGERS

Example 1 of a home task sheet for the student.

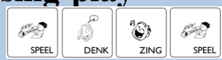
HOMETASKS LESSON 8



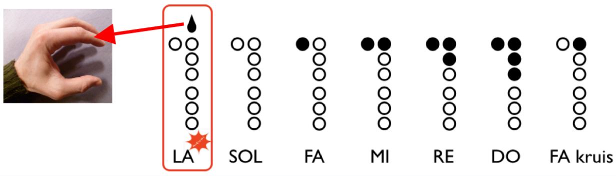
SOLFEGE: 2 new notes: a & c



Long notes (6 sec.) + "play-think-sing-play"

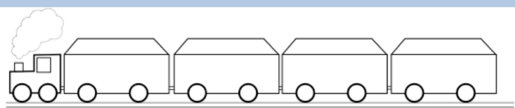


<u>Attention</u>: play "a" with side of index



Rhythms on a tone series
listen to the examples on the website.

Make your own song by using the "train"
Start with one note per rhythm …



play "Sinterklaas kapoentje" on the clarineo

listen to the song, you can find it on the website.

TWO-NOTES-EXERCISE
keep blowing …

1) f sharp – a – f sharp – a – f sharp – a …
2) g – a – g – a – g - a - …

Example 2 of a home task sheet for the student.

Music Paint Machine
MPM_EXP4_SCRIPTS *Lesson 21*

1. Welcome	
	How was it this week?
	Today, we are going to: …
2. 2notes exercise: b flat – e flat - f!!!	
	 introduce via game with note values

3. plat F Major: variations in tempo and dynamics: dirigent!!!		
3b)	each note 1 x 𝅝	
	each note 2 x 𝅗𝅥	
	each note 4 x ♩	
	each note **4 x** ♩♩	
3c)	same but now with movement ♩ ♩ ♩ ♩	GRID

A	B
LL1: mat	LL1: mat
LL2: play	all: play
LL3: count	

𝅝	i 1 colour per note
	ii 2 colour per note: colour/ 𝅗𝅥
	iii 2 colour per note: colour/ ♩
𝅗𝅥	i 1 colour per note
	ii 2 colour per note
♩	1 color per noot:
	1) other color per measure 2) other color per beat 3) other color per 2 beats

3d) F Major in 4/4 , 3/4 , 2/4: somebody counts, somebody plays, somebody conducts (soft-loud)
4. ketchup checkup & opblaas blues: with score
sing + play
c-e-g

Example of a lesson script

References

Addessi, A. R., Ferrari, L., Carlotti, S., & Pachet, F. (2006). Young children's musical experiences with a flow machine. Paper presented at the 9th International Conference of Music Perception and Cognition, Bologna, Italy.

Addessi, A. R., & Pachet, F. (2005). Experiments with a musical machine: musical style replication in 3 to 5 year old children. British Journal of Music Education, 22(01), 21-46.

Addessi, A. R., Pachet, F., & Caterina, R. (2004). Children Confronting an Interactive Musical System. Paper presented at the 8th International Conference on Music Perception & Cognition, Evanston, IL.

Addessi, A. R., & Volpe, G. (2011). The MIROR project. *Towards Ubiquitous Learning*, 15-28.

Addessi, A. R., & Young, S. (2009). Proceedings of the 4th Conference of the European Network of Music Educators and Researchers of Young Children. Bologna: Bononia University Press.

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology, 103*(1), 1-18.

Altenmuller, E., & Gruhn, W. (2002). Brain mechanisms. In R. Parncutt & G. E. McPherson (Eds.), The science and psychology of music performance: Creative strategies for teaching and learning (pp. 63-81). New York: Oxford University Press.

Amiel, T., & Reeves, T. C. (2008). Design-based research and educational technology: Rethinking technology and the research agenda. *Educational Technology & Society, 11*(4), 29-40.

Antonietti, A. (2009). Why is music effective in rehabilitation? *Studies in Health Technology and Informatics, 145*, 179-194.

Arsenault, D. (2005). *Dark Waters: Spotlight on Immersion.* Paper presented at the Game On North America Conference, Montreal, Canada.

Baber, C. (2003). *Cognition and tool use: forms of engagement in human and animal use of tools.* London: Taylor & Francis.

Bamberger, J. (1996). Turning music theory on its ear Do we hear what we see; Do we see what we say? *International Journal of Computers for Mathematical Learning, 1*(1), 33-55.

Bamberger, J. (1999). Learning from the children we teach. *Bulletin of the council for research in music education, 142*, 48-74.

Bamford, A. (2007). Kwaliteit en consistentie. Arts and cultural education in Flanders: CANON Cultural Unit.

Bandura, A. (1997). *Social Learning Theory*. Englewood Cliffs, NJ: Prentice Hall.

Bardram, J. (1997). *Plans as situated action: An activity theory approach to workflow systems.* Paper presented at the European Conference on Computer Supported Cooperative Work, Lancaster, UK.

Barrett, M. (1997). Invented notations: A view of young children's musical thinking. *Research Studies in Music Education, 8*(1), 2-14.

Bartel, L., & Cameron, L. (2004). From dilemmas to experience: Shaping the conditions of learning. In L. Bartel (Ed.), *Questioning the Music Education Paradigm*. Toronto: Canadian Music Educator's Association.

Bazzana, K. (1997). *Glenn Gould, the performer in the work: a study in performance practice*. Oxford: Clarendon Press.

Beckstead, D. (2001). Will Technology Transform Music Education. *Music Educators Journal, 87*(6), 44-49.

Bedny, G., & Harris, S. (2005). The systemic-structural theory of activity: Applications to the study of human work. *Mind, culture, and Activity, 12*(2), 128-147.

Bedny, G., & Karwowski, W. (2004). Activity theory as a basis for the study of work. *Ergonomics, 47*(2), 134-153.

Bedny, G., Karwowski, W., & Bedny, M. (2001). The principle of unity of cognition and behavior: Implications of activity theory for the study of human work. *International Journal of Cognitive Ergonomics, 5*(4), 401-420.

Behnke, E. (1989). At the Service of the Sonata: Music Lessons with Merleau-Ponty. *Merleau-Ponty: Critical Essays*, 23-29.

Benson, B. E. (2003). *The improvisation of musical dialogue: a phenomenology of music*. Cambridge, MA: Cambridge Univ Press.

Bevilacqua, F., Guédy, F., Schnell, N., Fléty, E., & Leroy, N. (2007). Wireless sensor interface and gesture-follower for music pedagogy. Paper presented at the 7th International Conference on New Interfaces for Musical Expression, New York, NY, NY, US.

Bevilacqua, F., Rasamimanana, N., Fléty, E., Lemouton, S., & Baschet, F. (2006). *The augmented violin project: research, composition and performance report.* Paper presented at the 2006 Conference on New Interfaces For Musical Expression (NIME06).

Biesta, G. (2007). Why 'what works' won't work: Evidence-based practice and the democratic deficit in educational research. *Educational Theory, 57*(1), 1-22.

Biocca, F. (2001). Inserting the presence of mind into a philosophy of presence: A response to Sheridan and Mantovani and Riva. *Presence: Teleoperators & Virtual Environments, 10*(5), 546-556.

Biocca, F., & Harms, C. (2002). *Defining and measuring social presence: Contribution to the networked minds theory and measure.* Paper presented at the PRESENCE, Porto, Portugal.

Biocca, F., & Nowak, K. (2002). Plugging your body into the telecommunication system: Mediated embodiment, media interfaces, and social virtual environments. In D. Atkin & C. Lin (Eds.), *Communication technology and society: Audience adoption and uses* (pp. 407-447). Cresskill, NJ: Hampton Press.

Blair, D. (2008). Do you hear what I hear? Musical maps and felt pathways of musical understanding. *Visions of Research in Music Education, 11*.

Bolden, B. (2009). Teaching composing in secondary school: A case study analysis. *British Journal of Music Education, 26*(2), 137-152.

Borchers, J. O. (1997). *WorldBeat: Designing a baton-based interface for an interactive music exhibit*. Paper presented at the ACM CHI'97 International Conference on Human Factors in Computing Systems, Atlanta, Georgia.

Bos, N. (2001). What do game designers know about scaffolding? Borrowing SimCity design principles for education. Retrieved November 17, 2011, from http://playspace.concord.org/papers.html#report

Bourgeau, A. (2006). L' audience de la musique hindoustanie. *Ethnographiques.org*(11). Retrieved from www.ethnographiques.org/2006/Bourgeau

Bowman, W. D. (2000). A somatic," here and now" semantic: Music, body, and self. *Bulletin of the Council for Research in Music Education*(144), 45-60.

Bowman, W. D. (2002). Educating musically. In R. Colwell & C. Richardson (Eds.), *The new handbook of research on music teaching and learning* (pp. 63-84). New York: Oxford University Press.

Bowman, W. D. (2004). Cognition and the body: Perspectives from music education. In L. Bresler (Ed.), *Knowing Bodies, Moving Minds: Towards Embodied Teaching and Learning* (pp. 29). Dordrecht: Kluwer Academic Publishers.

Bowman, W., & Powell, K. (2007). The body in a state of music. In Bresler, L. (2007). International handbook of research in arts education (Vol. 2, pp. 1087-1106). Dordrecht: Springer Verlag.

Brandmeyer, A., Hoppe, D., Sadakata, M., Timmers, R., & Desain, P. (2006). *PracticeSpace: A platform for real-time visual feedback in music instruction.* Paper presented at the 9th International Conference on Music Perception and Cognition, Bologna, Italy.

Brandmeyer, A., Timmers, R., Sadakata, M., & Desain, P. (2011). Learning expressive percussion performance under different visual feedback conditions. *Psychological research*, 75(2), 107-121.

Bransford, J. (2000). *How people learn: Brain, mind, experience, and school.* Washington, D.C.: National Academies Press.

Bresler, L. (2007). International handbook of research in arts education (Vol. 1 & 2). Dordrecht: Springer Verlag.

Broekkamp, H., & van Hout-Wolters, B. (2007). The gap between educational research and practice: A literature review, symposium, and questionnaire. *Educational Research and Evaluation, 13*(3), 203-220.

Brown, A. R. (2012). Experience design and interactive software in music education research. *Visions of Research in Music Education, 20.* Retrieved from http://www-usr.rider.edu/~vrme/v20n1/

Brown, E., & Cairns, P. (2004). *A grounded investigation of game immersion.* Paper presented at the CHI 2004, ACM Conference on Human Factors in Computing, Vienna, Austria.

Brown, T., & Lalor, A. (2009). The Movement Assessment Battery for Children-(MABC-2): a review and critique. *Physical & Occupational Therapy in Pediatrics, 29*(1), 86-103.

Bruner, J. S. (1960). *The process of education* (Vol. 115). Cambridge, MA: Harvard University Press.

Bruner, J. S. (1966). *Toward a theory of instruction.* Cambridge, MA: Harvard University Press.

Bruner, J. S. (1968). *Processes of cognitive growth: Infancy*. Worcester, MA: Clark University Press

Bruner, J. S. (1979). *On knowing: Essays for the left hand*. Cambridge, MA: Harvard University Press.

Bruner, J. S., Olver, R. R., & Greenfield, P. M. (1966). *Studies in cognitive growth*. New York: Wiley.

Buldu, M. (2010). Making learning visible in kindergarten classrooms: Pedagogical documentation as a formative assessment technique. Teaching and Teacher Education, 26(7), 1439-1449.

Burnard, P. (2007). Creativity and technology: Critical agents of change in the work and lives of music teachers. In J. Finney & P. Burnard (Eds.), *Music education with digital technology* (pp. 131-141). London: Continuum.

Burnard, P., & Younker, B. A. (2008). Investigating children's musical interactions within the activities systems of group composing and arranging: An application of Engeström's Activity Theory. *International Journal of Educational Research, 47*(1), 60-74.

Cadoz, C., & Wanderley, M. (2000). Gesture-music. In M. Wanderley & M. Battier (Eds.), *Trends in Gestural Control of Music* (pp. 71-93). Paris: Ircam - Centre Pompidou.

Campbell, K. H. (2011). Teacher as Researcher: An Essential Component of Teacher Preparation. *The Northwest Passage, 9*(2), 23-34.

Camurri, A., De Poli, G., Leman, M., & Volpe, G. (2001, November 2001). *A multi-layered conceptual framework for expressive gesture applications.* Paper presented at the MOSART Workshop, Barcelona, Spain.

Chaffin, R., & Logan, T. (2006). Practicing perfection: How concert soloists prepare for performance. *Advances in Cognitive Psychology, 2*(2), 113-130.

Chaffin, R., Lisboa, T., Logan, T., & Begosh, K. (2009). Preparing for memorized cello performance: The role of performance cues. *Psychology of Music, 38*, 3-30.

Chaiklin, S. (2003). The zone of proximal development in Vygotsky's analysis of learning and instruction. In A. Kozulin, B. Gindis, V. Ageyev & S. Miller (Eds.), *Vygotsky's educational theory in cultural context* (pp. 39-64). New York: Cambridge University Press.

Chamorro-Premuzic, T., & Furnham, A. (2007). Personality and music: Can traits explain how people use music in everyday life? *British Journal of Psychology, 98*(2), 175-185.

Chan, L., Jones, A., Scanlon, E., & Joiner, R. (2006). The use of ICT to support the development of practical music skills through acquiring keyboard skills: a classroom based study. *Computers & Education, 46*(4), 391-406.

Chandler, P. (2005). Music and Schema Theory. Retrieved from tzone.org/~okko/html/documents/music_and_cognition.pdf

Chen, H., Wigand, R., & Nilan, M. (1999). Optimal experience of Web activities. Computers in Human Behavior, 15(5), 585-608.

Chertoff, D. (2009). Exploring Additional Factors of Presence. Doctoral dissertation, University of Central Florida, Orlando, Florida.

Clark, A. (2007). Re-inventing ourselves: The plasticity of embodiment, sensing, and mind. *Journal of Medicine and Philosophy, 32*(3), 263-282.

Clark, A. (2008). Supersizing the mind: Embodiment, action, and cognitive extension. New York: Oxford University Press, USA.

Coffman, D. D. (2011). Music education research: quality and impact. In P. M. Ward-Steinman (Ed.), *Advances in Social-Psychology and Music Education Research*. Surrey: Ashgate Publishing Ltd.

Colpaert, J. (1999). User-driven development and content-based research. *Computer Assisted Language Learning*, 35-58.

Colpaert, J. (2006). Pedagogy-driven design for online language teaching and learning. *CALICO journal, 23*(3), 477.

Colprit, E. (2000). Observation and analysis of Suzuki string teaching. *Journal of Research in Music Education, 48*(3), 206.

Colwell, R. (2010). An Expanded Research Agenda for Music Education. In T. A. Regelski (Ed.), Music Education for Changing Times: Guiding Visions for Practice (pp. 139-148). Dordrecht: Springer.

Colwell, R. & Richardson, C. (Eds.) (2002). The new handbook of research on music teaching and learning. New York: Oxford University Press.

Costa-Giomi, E., Flowers, P. J., & Sasaki, W. (2005). Piano Lessons of Beginning Students Who Persist or Drop Out. *Journal of Research in Music Education, 53*(3), 234-247.

Costello, A. B., & Osborne, J. W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis [electronic version]. Practical Assessment Research & Evaluation, 10(7), 1-9.

Cox, M., Webb, M., Abbott, C., Blakeley, B., Beauchamp, T., & Rhodes, V. (2003). ICT and pedagogy, a review of the research literature: A report to the DfES. London: BECTA.

Creech, A. (2010). Learning a musical instrument: The case for parental support. *Music Education Research, 12*(1), 13-32.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper & Row.

Csikszentmihalyi, M. (1997). Assessing aesthetic education: Measuring the ability to "Ward off Chaos". *Arts Education Policy Review, 99*(1), 33-38.

Csikszentmihalyi, M. (2008). *Flow: The psychology of optimal experience*. New York: Harper Perennial

Csikszentmihalyi, M., Abuhamdeh, S., & Nakamura, J. (2005). Flow. In A. Elliot & C. DWeck (Eds.), *Handbook of competence and motivation* (pp. 598-608). New York: Guilford Press.

Custodero, L. A. (2002). Seeking challenge, finding skill: Flow experience and music education. Arts Education Policy Review, 103(3), 3-9.

Custodero, L. A. (2005). Observable indicators of flow experience: A developmental perspective on musical engagement in young children from infancy to school age. Music Education Research, 7(2), 185-209.

Custodero, L. A. (2010a). Meaning and experience. In H. F. Abeles & L. Custodero (Eds.), *Critical issues in music education* (pp. 61-68). New York: Oxford University Press.

Custodero, L. A. (2010b). Music learning and musical development. In H. F. Abeles & L. Custodero (Eds.), *Critical issues in music education* (pp. 113-142). New York: Oxford Univeristy press.

Dahlberg, G., Moss, P., & Pence, A. (1999). Beyond quality in early childhood education and care: Postmodern perspectives. London: Routledge.

Dalcroze, E. J. (1980). Rhyhtm, Music and Education. London: Dalcroze Society Inc.

Damasio, A. R. (1999). *The feeling of what happens: Body and emotion in the making of consciousness*. New York: Harcourt Brace.

Daniel, R. (2004). Peer assessment in musical performance: the development, trial and evaluation of a methodology for the Australian tertiary environment. British Journal of Music Education, 21(1), 89-110.

Dannenberg, R. B., Sanchez, M., Joseph, A., Capell, P., Joseph, R., & Saul, R. (1990). A computer-based multi-media tutor for beginning piano students. *Journal of New Music Research, 19*(2-3), 155-173.

Dannenberg, R. B., Sanchez, M., Joseph, A., Joseph, R., Saul, R., & Capell, P. (1993). *Results from the piano tutor project*. Paper presented at the the 4th Biennial Arts and Technology Symposium, Connecticut, USA.

Dant, T. (2004). The driver-car. *Theory Culture and Society, 21*, 61-80.

Davidson, J., & Correia, J. (2002). Body movement. In R. Parncutt & G. McPherson (Eds.), *The science and psychology of music performance: Creative strategies for teaching and learning* (pp. 237-250). New York: Oxford University Press.

Davidson, J. W., & Correia, J. S. (2001). Meaningful musical performance: A bodily experience. *Research Studies in Music Education, 17*(1), 70-83.

De Corte, E., Verschaffel, L., & Masui, C. (2004). The CLIA-model: A framework for designing powerful learning environments for thinking and problem solving. *European Journal of Psychology of Education, 19*(4), 365-384.

de Jong, T. (2010). Cognitive load theory, educational research, and instructional design: some food for thought. *Instructional science, 38*(2), 105-134.

De Poli, G. (2004). Methodologies for expressiveness modelling of and for music performance. *Journal of New Music Research, 33*(3), 189-202.

Decety, J., & Jackson, P. (2006). A social-neuroscience perspective on empathy. *Current directions in psychological science, 15*(2), 54-58.

Deliège, I., & Wiggins, G. (2006). Musical creativity: multidisciplinary research in theory and practice. New York: Psychology Press.

Deliège, I., & Wiggins, G. (2006). *Musical creativity: multidisciplinary research in theory and practice*. New York: Psychology Press.

Denis, G. (2006). *Pads'n'Swing, pour apprendre la musique en jouant.* Paper presented at the Rencontres des Jeunes Chercheurs en Environnements Informatiques pour l'Apprentissage Humain, Evry, France.

Denis, G., & Jouvelot, P. (2005). Motivation-driven educational game design: Applying best practices to music education. Paper presented at the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology.

Denissen, J. J. A., Geenen, R., van Aken, M. A. G., Gosling, S. D., & Potter, J. (2008). Development and validation of a Dutch translation of the Big Five Inventory (BFI). Journal of personality assessment, 90(2), 152-157.

Denissen, J. J. A., Geenen, R., Van Aken, M. A. G., Gosling, S. D., & Potter, J. (2008). Development and validation of a Dutch translation of the Big Five Inventory (BFI). *Journal of Personality Assessment, 90*(2), 152-157.

Desmet, F., Nijs, L., Demey, M., Lesaffre, M., Martens, J. P., & Leman, M. (2012). Assessing a Clarinet Player's Performer Gestures in Relation to Locally Intended Musical Targets. *Journal of New Music Research, 41*(1), 31-48.

Diseth, Ö. (2003). Personality and approaches to learning as predictors of academic achievement. *European Journal of Personality, 17*(2), 143-155.

Dixon, S., Goebl, W., & Widmer, G. (2005). The" Air Worm": An Interface for Real-Time Manipulation of Expressive Music Performance. Paper presented at the ICMC'05 International Computer Music Conference, Barcelona, Spain.

Dohn, N. (2002). Roles of the Body in Learning (Vol. Network for Non-scholastic learning). Aarhus, Danemark: Aarhus Universitet.

Dohn, N. (2006). *Affordances, a Merleau-Pontian Account.* Paper presented at the Fifth International. Conference on Networked Learning, Lancaster, UK.

Dourish, P. (2004). Where the action is: the foundations of embodied interaction. Cambridge MA: The MIT Press.

Draper, J. V., Kaber, D. B., & Usher, J. M. (1998). Telepresence. Human Factors: The Journal of the Human Factors and Ergonomics Society, 40(3), 354-375.

Duke, R. A. (1994). Making lasting change in musical performance: The rehearsal frame as a model for prescriptive analysis of music teaching. *Journal of Band Research, 30*, 78-95.

Duke, R. A. (1999a). Measures of instructional effectiveness in music research. *Bulletin of the council for research in music education, 143*, 1-48.

Duke, R. A. (1999b). Teacher and student behavior in Suzuki string lessons: Results from the International Research Symposium on Talent Education. *Journal of Research in Music Education, 47*(4), 293-307.

Duke, R. A., Prickett, C. A., & Jellison, J. A. (1998). Empirical description of the pace of music instruction. *Journal of Research in Music Education, 46*(2), 265-280.

Elby, A. (2000). What students' learning of representations tells us about constructivism. *The Journal of Mathematical Behavior, 19*(4), 481-502.

Elliott, D. (1995). Music matters. A new philosophy of music education. New York: Oxford University Press.

Elliott, D. (2005). Praxial music education: reflections and dialogues. New York: Oxford University Press.

Ericsson, K. (1997). Deliberate practice and the acquisition of expert performance: An overview. In H. Jørgensen & A. C. Lehmann (Eds.), Does practice make perfect? Current Theory and Research on Instrumental Music Practice. (pp. 9-51). Oslo: Norges musikkhùgskole.

Ericsson, K. (2003). Development of elite performance and deliberate practice: An update from the perspective of the expert-performance approach. In J. Starkes & K. Ericsson (Eds.), *Expert performance in sports. Advances in research on sport expertise* (pp. 49-81). Champaign, IL: Human Kinetics.

Ericsson, K., & Lehmann, A. (1996). Expert and exceptional performance: Evidence of maximal adaptation to task constraints. Annual Review of Psychology, 47(1), 273-305.

Ericsson, K., Krampe, R., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*(3), 363-363.

Ernst, M., & Bülthoff, H. (2004). Merging the senses into a robust percept. *Trends in Cognitive Sciences, 8*(4), 162-169.

Essl, G., & O'modhrain, S. (2006). An enactive approach to the design of new tangible musical instruments. *Organised sound, 11*(03), 285-296.

Everton, T., Galton, M., & Pell, T. (2000). Teachers' perspectives on educational research: Knowledge and context. *Journal of Education for Teaching: International Research and Pedagogy, 26*(2), 167-182.

Fein, E. C., & Klein, H. J. (2011). Personality Predictors of Behavioral Self-Regulation: Linking behavioral self-regulation to five-factor model factors, facets, and a compound trait. *International Journal of Selection and Assessment, 19*(2), 132-144.

Fels, S. (2000). *Intimacy and embodiment: implications for art and technology.* Paper presented at the ACM Conference on Multimedia, Los Angeles, CA, USA.

Ferguson, S. (2006). *Learning musical instrument skills through interactive sonification*. Paper presented at the the 2006 conference on New interfaces for musical expression (NIME06), Paris, France.

Ferguson, S., Moere, A., & Cabrera, D. (2005). Seeing sound: Real-time sound visualisation in visual feedback loops used for training musicians. Paper presented at the Tenth Symposium on Information Visualization, London.

Ferrari, L., Addessi, A. R., & Pachet, F. (2006). New technologies for new music education: The Continuator in a classroom setting *Proceedings of the International Conference on Music Perception and Cognition* (pp. 1392-1398).

Field, A. P. (2009). Discovering statistics using SPSS. London: SAGE publications Ltd.

Finneran, C. M., & Zhang, P. (2003). A person-artefact-task (PAT) model of flow antecedents in computer-mediated environments. International Journal of Human-Computer Studies, 59(4), 475-496.

Finney, J., & Burnard, P. (2009). Music education with digital technology. London: Continuum International Publishing Group.

Flanders, N. A. (1970). *Analyzing teaching behavior.* New York: Addison-Wesley Publishing Co.

Flohr, J. W. (1981). Short-term music instruction and young children's developmental music aptitude. *Journal of Research in Music Education, 29*(3), 219.

Fober, D., Letz, S., & Orlarey, Y. (2007). *VEMUS-Feedback and Groupware Technologies for Music Instrument Learning.* Paper presented at the 4th International Music Conference, Lefkada, Greece.

Folkestad, G. (2006). Formal and informal learning situations or practices vs formal and informal ways of learning. *British Journal of Music Education, 23*(02), 135-145.

Forgeard, M., Winner, E., Norton, A., & Schlaug, G. (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning. *PloS One, 3*(10), e3566.

François, R. R. J., Chew, E., & Thurmond, D. (2007). MIMI A Musical Improvisation System That Provides Visual Feedback to the Performer. University of Southern California Computer Science Department Technical Report No.07-889.

Frank, T., Michelbrink, M., Beckmann, H., & Schöllhorn, W. (2008). A quantitative dynamical systems approach to differential learning: self-organization principle and order parameter equations. *Biological Cybernetics, 98*(1), 19-31.

Frankel, J. (2010). Music education technology. In H. F. Abeles & L. A. Custodero (Eds.), *Critical issues in music education: Contemporary theory and practice*. New York: Oxford University Press.

Friberg, A., Bresin, R., & Sundberg, J. (2006). Overview of the KTH rule system for musical performance. *Advances in Cognitive Psychology, 2*(2), 145-161.

Fruyt, F. D., & Vollrath, M. (2003). Inter-parent agreement on higher and lower level traits in two countries: Effects of parent and child gender. *Personality and individual differences, 35*(2), 289-301.

Gardner, H. (1985). *Frames of mind: The theory of multiple intelligences*. New York: Basic books.

Gardner, H. (1990). *Art education and human development* (Vol. 3). Los Angeles: The Getty Center for Education in the Arts.

Gaunt, H. (2009). One-to-one tuition in a conservatoire: the perceptions of instrumental and vocal students. *Psychology of Music, 38*(2), 178-208.

Gembris, H., & Davidson, J. W. (2002). Environmental influences. *The science and psychology of music performance: Creative strategies for teaching and learning*, 17-30.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. *Synthese, 80*(1), 121-140.

Godlovitch, S. (1998). *Musical performance: A philosophical study*. London: Routledge.

Godoy, R., & Leman, M. (2010). Musical gestures: Sound, movement, and meaning. New York: Routledge

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in neurosciences, 15*(1), 20-25.

Goolsby, T. W. (1995). Portfolio assessment for better evaluation. Music Educators Journal, 82(3), 39.

Goolsby, T. W. (1997). Verbal instruction in instrumental rehearsals: A comparison of three career levels and preservice teachers. *Journal of Research in Music Education, 45*(1), 21-40.

Gordon, E. E. (1986). *Manual for the Primary Measures of Music Audiation: And, the Intermediate Measures of Music Audiation*. Chicago, IL: GIA Publications.

Gordon, E. E. (1997). *Learning sequences in music: Skill, content, and patterns*. Chicago, IL: GIA Publications.

Gordon, E. E. (2007). *Learning sequences in music: A contemporary music learning theory*. Chicago, IL: GIA Publications.

Gould, S. J. (1995). Researcher introspection as a method in consumer research: Applications, issues, and implications. *The Journal of Consumer Research, 21*(4), 719-722.

Gruhn, W. (1999). The development of mental representations in early childhood: a longitudinal study on music learning. In S. W. Yi (Ed.), *Music, Mind, and Science* (pp. 434-453). Seoul: Seoul National University Press.

Gruhn, W. (2002). Phases and stages in early music learning. A longitudinal study on the development of young children's musical potential. *Music Education Research, 4*(1), 51-71.

Hadjakos, A., Aitenbichler, E., & Mühlhäuser, M. (2008a). *Syssomo: A pedagogical tool for analyzing movement variants between different pianists*. Paper presented at the 5th International Conference on Enactive Interfaces (Enactive08), Pisa, Italy.

Hadjakos, A., Aitenbichler, E., & Mühlhäuser, M. (2008b). *The elbow piano: Sonification of piano playing movements*. Paper presented at the 8th International Conference on New Interfaces for Musical Expression (NIME 2008), Genova, Italy.

Hallam, S. (1998). The predictors of achievement and dropout in instrumental tuition. *Psychology of Music, 26*(2), 116-132.

Hallam, S. (2004). *How important is practicing as a predictor of learning outcomes in instrumental music?* Paper presented at the 8th International Conference on Music Perception & Cognition, Evanston, IL.

Hallam, S. (2006). *Music psychology in education* (Vol. 25). London: Institute of Education.

Hämäläinen, P., Mäki-Patola, T., Pulkki, V., & Airas, M. (2004). *Musical computer games played by singing*. Paper presented at the 7th International Conference On digital Audio Effects (DAFx'04), Naples, Italy.

Hargreaves, D. J., & North, A. C. (1997). *The social psychology of music*: Oxford University Press.

Hashida, M., Tanaka, S., & Katayose, H. (2009). *Mixtract: A directable musical expression system.* Paper presented at the Affective Computing and Intelligent Interaction, Amsterdam, NL.

Heikinheimo, T. (2009). *Intensity of interaction in instrumental music lessons.* Sibelius Academy, Helsinki, FI.

Heller, J., & O'Connor, E. (2002). Maintaining quality in research and reporting. In R. Colwell & C. Richardson (Eds.), *The new handbook of research on music teaching and learning* (pp. 1089-1107). New York: Oxford University Press.

Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2007). *Movement assessment battery for children-2, second edition (Movement ABC-2).* London: Harcourt Assessment.

Hennessy, S. (2001). Research and development in music education. In C. Philpott & C. Plummeridge (Eds.), *Issues in music teaching* (pp. 238-251). London: Routledge.

Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution, and change. *Journal of Curriculum Studies, 37*(2), 155-192.

Hirose, N. (2002). An ecological approach to embodiment and cognition. *Cognitive Systems Research, 3*(3), 289-299.

Holmes, N., & Spence, C. (2004). The body schema and multisensory representation(s) of peripersonal space. *Cognitive processing, 5*(2), 94-105.

Hoppe, D., Brandmeyer, A., Sadakata, M., Timmers, R., & Desain, P. (2006). *The effect of real-time visual feedback on the training of expressive performance skills.* Paper presented at the 9th International Conference on Music Perception and Cognition (ICMPC9).

Hoppe, D., Sadakata, M., & Desain, P. (2006). Development of real-time visual feedback assistance in singing training: a review. Journal of computer assisted learning, 22(4), 308-316.

Howard, D. M., Brereton, J., Welch, G. F., Himonides, E., DeCosta, M., Williams, J., et al. (2007). Are real-time displays of benefit in the singing studio? An exploratory study. *Journal of Voice, 21*(1), 20-34.

Howard, D. M., Welch, G. F., Brereton, J., Himonides, E., DeCosta, M., Williams, J., & Howard, A.W. (2004). WinSingad: A real-time display for the singing studio. Logopedics Phonatrics Vocology, 29(3), 135-144.

Hultberg, C. (2000). *The printed score as a mediator of musical meaning approaches to music notation in western tonal music.* Malmö Academy of Music, Dept. of Research in Music Education, Malmö.

Ijsselsteijn, W., & Riva, G. (2003). Being There: The experience of presence in mediated environments. In G. Riva, F. Davide & W. A. IJsselsteijn (Eds.), Being There: Concepts, effects and measurement of user presence in synthetic environments. Amsterdam, The Netherlands: Ios Press.

Ilari, B., & Gluschankof, C. (2009). Music in the early years: Research, theory and practice. Early Child Development and Care, 179(6).

Iwami, N., & Miura, M. (2007). *A support system for basic practice of playing the drums*. Paper presented at the International Computer Music Conference, Copenhagen, Denmark.

Jackson, S. A., & Eklund, R. C. (2004). The flow scales manual. Morgantown, WV: Fitness Information Technology.

Jacobson, D. (2001). Presence revisited: Imagination, competence, and activity in text-based virtual worlds. CyberPsychology & Behavior, 4(6), 653-673.

Jacobson, D. (2002). On theorizing presence. Journal of Virtual Environments, 6(1).

Jaques-Dalcroze, E. (1921). Rhythm, music and education. New York: GP Putnam's sons.

Jensenius, A. R., Wanderley, M., Godoy, R., & Leman, M. (2010). Musical gestures: concepts and methods in research. In R. Godoy & M. Leman (Eds.), *Music, Gesture, and the Formation of Embodied Meaning* (pp. 12-35). New York: Routledge.

Johnson, D., & Han, D. (2009). Music Coach: Real-time Evaluation of Music Performance using Nokia N900. Santa Barbara: University of California, Dpt. of computer sciences.

Johnson, R., van der Linden, J., & Rogers, Y. (2010). *MusicJacket: the efficacy of real-time vibrotactile feedback for learning to play the violin*. Paper presented at the 28th International Conference on Human Factors in Computing Systems, Atlanta Georgia, USA.

Johnston, A., Amitani, S., & Edmonds, E. (2005). *Amplifying reflective thinking in musical performance*.

Jordon, S. (2001). Embodied Pedagogy: The body and teaching theology. *Teaching Theology & Religion, 4*(2), 98-101.

Jorgensen, E. R. (2008). *The art of teaching music*. Bloomington: Indiana University Press.

Juntunen, M., & Westerlund, H. (2001). Digging Dalcroze, or, Dissolving the Mind–Body Dualism: philosophical and practical remarks on the musical body in action. *Music Education Research, 3*(2), 203-214.

Kaptelinin, V. (1996a). Activity theory: Implications for human-computer interaction. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 103-116). Cambridge, MA: The MIT Press.

Kaptelinin, V. (1996b). Computer-mediated activity: Functional organs in social and developmental contexts. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 45-68). Cambridge, MA: MIT Press.

Kaptelinin, V., & Nardi, B. A. (2006). *Acting with technology: Activity theory and interaction design*. London: The MIT Press.

Karlsson, J., & Juslin, P. (2008). Musical expression: an observational study of instrumental teaching. *Psychology of Music, 36*(3), 309.

Karpatschof, B. (2006). *Human activity-contributions to the anthropological sciences from a perspective of activity theory*. Copenhagen: Dansk Psykologisk Forlag.

Kennell, R. (2002). Systematic research in studio instruction in music. In R. Colwell (Ed.), *The new handbook of research on music teaching and learning* (pp. 243-256). New York: Oxford University Press.

Kiesler, S. (1992). Talking, teaching, and learning in network groups: Lessons from research. In A. Kaye (Ed.), *NATO advanced workshop on collaborative learning through computer conferencing* (pp. 145-165). Heidelberg: Springer-Verlag.

Klein, H. J., & Lee, S. (2006). The effects of personality on learning: The mediating role of goal setting. *Human Performance, 19*(1), 43-66.

Koehler, M. J., & Mishra, P. (2005a). Teachers learning technology by design. *Journal of Computing in Teacher Education, 21*(3), 94-102.

Koehler, M. J., & Mishra, P. (2005b). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research, 32*(2), 131-152.

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge. *Contemporary Issues in Technology and Teacher Education, 9*(1), 60-70.

Koehler, M. J., Mishra, P., Yahya, K., & Yadav, A. (2004). *Successful teaching with technology: The complex interplay of content, pedagogy, and technology*. Paper presented at the Proceedings from the Annual Meeting of the Society for Information Technology & Teacher Education, Atlanta, GA.

Komarraju, M., Karau, S. J., & Schmeck, R. R. (2009). Role of the Big Five personality traits in predicting college students' academic motivation and achievement. *Learning and Individual Differences, 19*(1), 47-52.

Komarraju, M., Karau, S. J., Schmeck, R. R., & Avdic, A. (2011). The Big Five personality traits, learning styles, and academic achievement. *Personality and individual differences, 51*(4), 472-477.

Koutsoupidou, T., & Hargreaves, D. J. (2009). An experimental study of the effects of improvisation on the development of children's creative thinking in music. *Psychology of Music, 37*(3), 251-278.

Kratus, J. (1991). Growing with improvisation. Music Educators Journal, 78(4), 35-40.

Kun, J. V. (2004). A real-time responsive/interactive system for musical conducting using motion capture technology. Unpublished doctoral dissertation, Arizona State University-Tempe.

Laarni, J., Ravaja, N., Saari, T., & Hartmann, T. (2004). Personality-related differences in subjective presence. In M. Alcañiz Raya & B. Rey Solaz (Eds.), Proceedings of the PRESENCE 2004 (pp. 88-95). Valencia, Spain: Editorial de la UPV.

Lappe, C., Herholz, S. C., Trainor, L.J., & Pantev, C. (2008). Cortical plasticity induced by short-term unimodal and multimodal musical training. The journal of neuroscience, 28(39), 9632.

Larkin, O., Koerselman, T., Ong, B., & Ng, K. (2008). *Sonification of bowing features for string instrument training*. Paper presented at the 4th International Conference on Auditory Display, Paris, France,.

Lehmann, A. (1997). Acquired mental representations in music performance: Anecdotal and preliminary empirical evidence. In H. Jørgensen & A. C. Lehmann. Does practice make perfect? Current Theory and Research on Instrumental Music Practice. (pp. 141-163). Oslo: Norges musikkhùgskole.

Lehmann, A. C., Sloboda, J. A., & Woody, R. H. (2007). *Psychology for musicians: Understanding and acquiring the skills*. New York: Oxford University Press.

Leman, M. (2007). Embodied music cognition and mediation technology. London: The MIT Press.

Leman, M., & Camurri, A. (2006). Understanding musical expressiveness using interactive multimedia platforms. *Musicae scientiae, 10*(1), 209-233.

Leman, M., Desmet, F., Styns, F., Van Noorden, L., & Moelants, D. (2009). Sharing Musical Expression Through Embodied Listening: A Case Study Based on Chinese Guqin Music. *Music Perception, 26*(3), 263-278.

Leman, M., Lesaffre, M., Nijs, L., & Deweppe, A. (2010). User-oriented Studies in Embodied Music cognition. Musicae Scientiae (Special Issue: Understanding musical structure and form: papers in honour of Irène Deliège), 203 -224.

Lim, F. V., O'Halloran, K. L., & Podlasov, A. (2012). Spatial pedagogy: mapping meanings in the use of classroom space. *Cambridge Journal of Education, 42*(2), 235-251.

Lim, K. A., & Raphael, C. (2009). *Intune: A musician' s intonation visualization system*.

Lim, K. A., & Raphael, C. (2010). Intune: A system to support an instrumentalist's visualization of intonation. *Computer Music Journal, 34*(3), 45-55.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. Journal of computer-mediated communication, 3(2), 20.

Loomis, J. (1992). Distal attribution and presence. Presence: Teleoperators and Virtual Environments, 1(1), 113-119.
Loyens, S. M. M., & Gijbels, D. (2008). Understanding the effects of constructivist learning environments: Introducing a multi-directional approach. *Instructional science, 36*(5), 351-357.
MacDonald, M. (2007). Toward formative assessment: The use of pedagogical documentation in early elementary classrooms. Early Childhood Research Quarterly, 22(2), 232-242.
MacDonald, R., Byrne, C., & Carlton, L. (2006). Creativity and flow in musical composition: An empirical investigation. Psychology of Music, 34(3), 292.
Macmillan, J. (2004). Learning the piano: a study of attitudes to parental involvement. *British Journal of Music Education, 21*(03), 295-311.
Manzo, V. (2011). *Max/MSP/Jitter for Music*. New York: Oxford University Press.
Maravita, A., & Iriki, A. (2004). Tools for the body (schema). *Trends in Cognitive Sciences, 8*(2), 79-86.
Maréchal, G. (2009). Constructivism. In A. J. Mills, G. Durepos & E. Wiebe (Eds.), *Encyclopedia of Case Study Research* (pp. 220-225). London: Sage.
Maslovat, D., Brunke, K. M., Chua, R., & Franks, I. M. (2009). Feedback effects on learning a novel bimanual coordination pattern: support for the guidance hypothesis. *Journal of motor behavior, 41*(1), 45-54.
Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? *American Psychologist, 59*(1), 14.
Mayer, R. E., Moreno, R., Boire, M., & Vagge, S. (1999). Maximizing constructivist learning from multimedia communications by minimizing cognitive load. *Journal of Educational Psychology, 91*(4), 638.
McPherson, G. E. (2006). *The Child as Musician-A Handbook of Musical Development*. New York: Oxford University Press.
McPherson, G. E. (2009). The role of parents in children's musical development. *Psychology of Music, 37*(1), 91-110.
McPherson, G. E., & Davidson, J. W. (2002). Musical practice: Mother and child interactions during the first year of learning an instrument. *Music Education Research, 4*(1), 141-156.
McPherson, G. E., & Gabrielsson, A. (2002). From sound to sign. In R. Parncutt & G. McPherson (Eds.), *The science and psychology of music performance: Creative strategies for teaching and learning* (pp. 99-116). New York: Oxford University Press.
McPherson, G. E., & Zimmerman, B. J. (2002). Self-regulation of musical learning. In R. Colwell & C. Richardson (Eds.), *The new handbook of research on music teaching and learning* (pp. 327-347). New York: Oxford University Press.
Meredith, M. A. (2002). On the neuronal basis for multisensory convergence: a brief overview. *Cognitive Brain Research, 14*(1), 31-40.
Merleau-Ponty, M. (1945). Phénoménologie de la perception. *Paris, Edition Gallimard*.
Mervielde, I., & De Fruyt, F. (1999). *Construction of the Hierarchical Personality Inventory for Children (HiPIC).* Paper presented at the Eight European Conference on Personality Psychology Tilburg.
Mills, J. (2004). Working in music: Becoming a performer-teacher. *Music Education Research, 6*(3), 245-261.
Mishra, P., & Koehler, M. J. (2003). Not "what" but "how": Becoming design-wise about educational technology. In Y. Zhao (Ed.), *What teachers should know about technology: Perspectives and practices* (pp. 99-122). Greenwich, CT: Information Age Publisher.
Mize, C. D., & Gibbons, A. (2000). *More than inventory: Effective integration of instructional technology to support student learning in K-12 schools*. Paper presented at the Society

for Information Technology & Teacher Education International Conference, San Diego, CA.

Moore, R. E., Estis, J., Gordon-Hickey, S., & Watts, C. (2008). Pitch discrimination and pitch matching abilities with vocal and nonvocal stimuli. *Journal of Voice, 22*(4), 399-407.

Moreno, R., & Mayer, R. (2007). Interactive multimodal learning environments. *Educational Psychology Review, 19*(3), 309-326.

Morrison, S. J., & Fyk, J. (2002). Intonation. In R. Parncutt & G. McPherson (Eds.), *The science and psychology of music performance: Creative strategies for teaching and learning* (pp. 183-197). New York: Oxford University Press.

Mulder, A. (2004). Towards a choice of gestural constraints for instrumental performers. Trends in Gestural Control of Music, 315–335.

Nacke, L., & Lindley, C. (2008). Flow and immersion in first-person shooters: measuring the player's gameplay experience. Paper presented at the Conference on Future Play: Research, Play, Share Toronto, Ontario, Canada.

Nardi, B. (1996). Activity theory and human-computer interaction. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 7-16). Cambridge, MA: MIT Press.

Naveda, L., & Leman, M. (2009). A Cross-modal Heuristic for Periodic Pattern Analysis of Samba Music and Dance. *Journal of New Music Research, 38*(3), 255-283.

Ng, K. C., Weyde, T., & Nesi, P. (2008). *i-Maestro: Technology-enhanced learning for music.* Paper presented at the International Computer Music Conference (ICMC), Belfast.

Ng, K., Larkin, O., Koerselman, T., & Ong, B. (2007). i-Maestro gesture and posture support: 3d motion data visualisation for music learning and playing. Paper presented at the EVA 2007 London International Conference, London.

Ng, K. C., Weyde, T., Larkin, O., Neubarth, K., Koerselman, T., & Ong, B. (2007). *3d augmented mirror: a multimodal interface for string instrument learning and teaching with gesture support.* Paper presented at the 9th International Conference on Multimodal Interfaces, Nagoya, Japan.

Nideffer, R. (2002). Getting Into The Optimal Performance State. Retrieved from www.taisdata.com/articles/optimal.pdf

Nijs, L. (2008). Evaluatie in het DKO: Het schietlood in actie [Assessment in Part time music education: handling the plum line]. In van Petegem. Begeleid zelfstandig leren, Alternatieve evaluatie 6(21). Mechelen, Wolters Plantyn.

Nijs, L., Lesaffre, M., & Leman, M. (2009). The musical instrument as a natural extension of the musician. Paper presented at the Fifth Conference on Interdisciplinary Musicology, Paris, France.

Nijs, L., M. Lesaffre & M. Leman (in press). The musical instrument as a natural extension of the musician. In: Castellengo, M. & Genevois, H. Music and its instruments. Sampzon, Editions Delatour France.

Nijs, L., Moens, B., Lesaffre, M., & Leman, M. (2012). The Music Paint Machine: Stimulating Self-monitoring Through the Generation of Creative Visual Output Using a Technology-enhanced Learning Tool. *Journal of New Music Research, 41*(1), 79-101.

Nijs, L., P. Coussement, C. Muller, M. Lesaffre & M. Leman (2010). The Music Paint Machine. A multimodal interactive platform to stimulate musical creativity in instrumental practice. In José A. Moinhos Cordeiro, Boris Shishkov, Alexander Verbraeck, Markus Helfert (Eds.) (2010). Proceedings of the Second International Conference on Computer Supported Education, Valencia, Spain, April 7-10, 2010 - Volume 1. INSTICC Press 2010

Nilsson, B., & Folkestad, G. (2005). Children's practice of computer-based composition. Music Education Research, 7(1), 21-37.

Norton, A., Winner, E., Cronin, K., Overy, K., Lee, D. J., & Schlaug, G. (2005). Are there pre-existing neural, cognitive, or motoric markers for musical ability? *Brain and cognition, 59*(2), 124-134.

Nosulenko, V., Barabanshikov, V., Brushlinsky, A., & Rabardel, P. (2005). Man-technology interaction: some of the Russian approaches. Theoretical Issues in Ergonomics Science, 6(5), 359-383.

Novak, T. P., Hoffman, D. L., & Yung, Y. F. (2000). Measuring the customer experience in online environments: A structural modeling approach. Marketing Science, 19(1), 22-42.

OECD. (2010). *Inspired by Technology, Driven by Pedagogy: A Systemic Approach to Technology-Based School Innovations*. Paris: Center for Educationa Research and Innovation.

Olsson, L. (2009). Movement and experimentation in young children's learning: Deleuze and Guattari in early childhood education. London: Routledge.

Ormrod, J. E. (1990). *Human learning: principles, theories, and educational applications*. New York: Merrill Publishing Company.

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational psychologist, 38*(1), 1-4.

Pacherie, E. (2006). Towards a dynamic theory of intentions. In S. Pockett, W. Banks & S. gallagher (Eds.), *Does consciousness cause behavior? An investigation of the nature of volition*. London: The MIT Press.

Pacherie, E. (2008). The phenomenology of action: A conceptual framework. *Cognition, 107*(1), 179-217.

Pachet, F. (2002). *The continuator: Musical interaction with style.* Paper presented at the Stockholm Music Performance Symposium, Stockholm, Sweden.

Pachet, F. (2002a). Interacting with a musical learning system: the Continuator. In C. Anagnostopoulou, M. Ferrand & A. Smaill (Eds.), Music and Artificial Intelligence, Lecture Notes in Artificial Intelligenc (Vol. 2445, pp. 119-132). Berlin Heidelberg: Springer Verlag

Pachet, F. (2002b). Playing with virtual musicians: The continuator in practice. *IEEE MultiMedia, 9*(3), 77-82.

Pachet, F. (2006). Enhancing individual creativity with interactive musical reflexive systems. In I. Deliège & G. A. Wiggins (Eds.), *Musical Creativity: Multidisciplinary research in theory and practice* (pp. 359). New York: Psychology Press.

Paivio, A. (2007). *Mind and its evolution: A dual coding theoretical approach*. Mahwah, N.J.: Lawrence Erlbaum Associates Publishers.

Palmer, C., & Drake, C. (1997). Monitoring and planning capacities in the acquisition of music performance skills. Canadian Journal of Experimental Psychology, 51(4), 369-384.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books, Inc.

Papert, S. (1987). Computer criticism vs. technocentric thinking. *Educational Researcher, 16*(1), 22-30.

Park, S. B., & Hwang, H. (2009). Understanding online game addiction: Connection between presence and flow. Human-Computer Interaction. Interacting in Various Application Domains, 378-386.

Paul, S. J., & Ballantine, J. H. (2002). The sociology of education and connections to music education research. In R. Colwell & C. Richardson (Eds.), *The new handbook of research on music teaching and learning* (Vol. 2, pp. 566-580). New York, NY: Oxford University Press.

Pederiva, P., & Galvão, A. (2005). The construction and experience of the body during musical performance. *Performance Online, 1*(1).

Percival, G., Wang, Y., & Tzanetakis, G. (2007). *Effective use of multimedia for computer-assisted musical instrument tutoring.* Paper presented at the International Workshop on Educational Multimedia and Multimedia Education (Augsburg, Bavaria, Germany.

Perkins, D. N. (1992). Technology meets constructivism: Do they make a marriage. In T. M. Duffy & D. H. Jonassen (Eds.), Constructivism and the technology of instruction: A conversation (pp. 45-55). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Persson, R. S. (1994). Control before shape-on mastering the clarinet: A case study on commonsense teaching. *British Journal of Music Education, 11*(3), 223-238.

Pezzulo, G. (2007). Schemas and Schema-based Architectures: Istituto di Linguistica Computazionale "Antonio Zampolli" of the National Research Council of

Pezzulo, G. (2011). Grounding procedural and declarative knowledge in sensorimotor anticipation. *Mind & Language, 26*(1), 78-114.

Pezzulo, G., & Castelfranchi, C. (2007). The symbol detachment problem. *Cognitive processing, 8*(2), 115-131.

Phillips-Silver, J., & Trainor, L. J. (2005). Feeling the beat: Movement influences infant rhythm perception. *Science, 308*(5727), 1430-1430.

Piaget, J. (1954). *The construction of reality in the child*. New York, NY: Basic Books.

Pierce, A. (2007). *Deepening musical performance through movement: the theory and practice of embodied interpretation*. Bloomington and Indianapolis: Indiana University Press.

Polanyi M (1958). Personal knowledge: towards a post-critical philosophy. London: Routledge

Polanyi, M. (1967). *The tacit dimension*. New York, NY: Anchor Books.

Polkinghorne, D. (2004). Practice and the human sciences: The case for a judgment-based practice of care. Albany: State University of New York, NY Press.

Polly, D. (2011). Teachers' learning while constructing technology,Äêbased instructional resources. *British Journal of Educational Technology, 42*(6), 950-961.

Pritchard, A., & Woollard, J. (2010). Psychology for the classroom: constructivism and social learning. New York, NY: Routledge.

Puckette, M. S., Apel, T., & Zicarelli, D. D. (1998). Real-time audio analysis tools for Pd and MSP. Paper presented at the International Computer Music Conference, San Francisco, California.

Puustinen, M., & Pulkkinen, L. (2001). Models of self-regulated learning: A review. *Scandinavian Journal of Educational Research, 45*(3), 269-286.

Rabardel, P. (1995). *Les Hommes et les technologies: approche cognitive des instruments contemporains*. Paris: Armand Collin.

Rabardel, P. (2001). Instrument mediated activity in situations. In A. Blandford, J. Vanderdonckt & P. Gray (Eds.), *People and Computers XV - Interaction without Frontiers* (pp. 17-30). Berlin: Springer-Verlag.

Rabardel, P. (2002). People and technology: A cognitive approach to contemporary instruments. Retrieved from http://ergoserv.psy.univ-paris8.fr/ Rabardel

Rabardel, P., & Beguin, P. (2005). Instrument mediated activity: from subject development to anthropocentric design. *Theoretical Issues in Ergonomics Science, 6*(5), 429-461.

Rabardel, P., & Bourmaud, G. (2003). From computer to instrument system: a developmental perspective. *Interacting with Computers, 15*(5), 665-691.

Rados, K., Kovacevic, P., Bogunovic, B., Ignjatovic, T., & Acic, G. (2003). *Psychological foundations of success in learning music at elementary school age*. Paper presented at the Triennial Conference of the European Society for theCognitive Science of Music (ESCOM), Hannover, germany.

Rae, G., & McCambridge, K. (2004). Correlates of performance anxiety in practical music exams. *Psychology of Music, 32*(4), 432-439.

Raptis, S., Chalamandaris, A., Baxevanis, A., Askenfeld, A., Schoonderwaldt, E., Hansen, K. F., et al. (2005). *Imutus-an effective practicing environment for music tuition.* Paper presented at the International Computer Music Conference (ICMC 2005), Barcelone, Spain.

Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. IEEE Transactions on Systems, Man, and Cybernetics, 13(3), 257-266.

Raulin, M. L., & Graziano, A. M. (1994). Quasi-experiments and correlational studies. In A. M. Colman (Ed.), *Companion encyclopaedia of psychology* (Vol. 2, pp. 1122-1141). London: Routledge.

Rebelo, P. (2006). Haptic sensation and instrumental transgression. *Contemporary Music Review, 25*(1), 27-35.

Regelski, T. A. (1994). Action research and critical theory: Empowering music teachers to professionalize praxis. *Bulletin of the council for research in music education*(123), 63-89.

Reimer, B. (1992). An agenda for music teacher education. *Journal of Music Teacher Education, 5*(11).

Rentfrow, P. J., & Gosling, S. D. (2003). The do re mi's of everyday life: the structure and personality correlates of music preferences. *Journal of personality and social psychology, 84*(6), 1236.

Reybrouck, M., Verschaffel, L., & Lauwerier, S. (2009). Children's graphical notations as representational tools for musical sense-making in a music-listening task. *British Journal of Music Education, 26*(02), 189-211.

Reyes, M. R., Brackett, M. A., Rivers, S. E., White, M., & Salovey, P. (2012). Classroom emotional climate, student engagement, and academic achievement. *Journal of Educational Psychology, 104*(3), 700.

Reynolds-Keefer, L., & Johnson, R. Is a picture is worth a thousand words? Creating effective questionnaires with pictures. *Practical Assessment, Research & Evaluation, 16*(8), 2.

Riva, G. (2005). The psychology of ambient intelligence: Activity, situation and presence. In G. Riva, M. Anguera, B. Wiederhold & F. Mantovani (Eds.). From Communication to Presence: Cognition, Emotions and Culture towards the Ultimate Communicative Experience: festschrift in honor of Luigi Anolli (pp. 19-34). Amsterdam: IOS Press.

Riva, G. (2006). Being-in-the-world-with: presence meets social and cognitive neuroscience. In G. Riva, M. Anguerra, B. Wiederhold & F. Mantovani (Eds.), *From communication to presence: Cognition, emotions and culture towards the ultimate communicative experience* (pp. 47-80). Amsterdam: IOS Press.

Riva, G. (2006). From communication to presence: cognition, emotions, and culture towards the ultimate communicative experience: festschrift in honor of Luigi Anolli. Amsterdam: Ios Press.

Riva, G. (2008). Enacting interactivity: The role of presence. In F. Morganti, A. Carassa & G. Riva (Eds.), Enacting Intersubjectivity: A cognitive and social perspective on the study of interactions (pp. 97-114). Amsterdam: IOS Press.

Riva, G. (2008b). Presence and Social Presence: From Agency to Self and Others. Paper presented at the 1st Annual International Workshop on Presence, Padova, Italy.

Riva, G. (2009). Is presence a technology issue? Some insights from cognitive sciences. *Virtual Reality, 13*(3), 159-169.

Riva, G., Castelnuovo, G., & Mantovani, F. (2006). Transformation of flow in rehabilitation: The role of advanced communication technologies. Behavior research methods, 38(2), 237-244.

Riva, G., Mantovani, F., & Gaggioli, A. (2004). Presence and rehabilitation: toward second-generation virtual reality applications in neuropsychology. Journal of NeuroEngineering and Rehabilitation, 1(1), 9.

Riva, G., Waterworth, J. A., & Waterworth, E. L. (2004). The layers of presence: a bio-cultural approach to understanding presence in natural and mediated environments. CyberPsychology & Behavior, 7(4), 402-416.

Riva, G., Waterworth, J. A., Waterworth, E. L., & Mantovani, F. (2009). From intention to action: The role of presence. New Ideas in Psychology, 29(1), 24-37.

Roberts, B. (1994). Music teachers as researchers. *International Journal of Music Education, 23*(1), 24-33.

Robine, M., Percival, G., & Lagrange, M. (2007). *Analysis of saxophone performance for computer-assisted tutoring*. Paper presented at the 2007 International Computer Music Conference, San Francisco, USA.

Rod, M. (2011). Subjective personal introspection in action-oriented research. *Qualitative Research in Organizations and Management: An International Journal, 6*(1), 6-25.

Romero, P., & Calvillo-Gámez, E. H. (2011). Towards an embodied view of flow. Paper presented at the International Workshop on User Models for Motivational Systems: the affective and the rational routes to persuasion (UMMS 2011), Girona, Spain.

Ronsse, R., Puttemans, V., Coxon, J. P., Goble, D. J., Wagemans, J., Wenderoth, N., et al. (2011). Motor Learning with Augmented Feedback: Modality-Dependent Behavioral and Neural Consequences. *Cerebral Cortex, 21*(6), 1283-1294.

Rostvall, A. L., & West, T. (2003). Analysis of interaction and learning in instrumental teaching. *Music Education Research, 5*(3), 213-226.

Rostvall, A. L., & West, T. (2008). Theoretical and methodological perspectives on designing video studies of interaction. *International journal of qualitative methods, 4*(4), 87-108.

Rudolph, T. E. (2005). *Technology strategies for music education*. Milwaukee, WI: Hal Leonard Publishing Corporation.

Russell, J. (2003). Core affect and the psychological construction of emotion. *Psychological review, 110*(1), 145-172.

Russell, J. A. (1996). Agency: Its role in mental development. Hove, U.K.: Erlbaum.

Russell, J. E. (1997). Autism as an executive disorder. New York, NY: Oxford University Press.

Rutkowski, J. (1996). The effectiveness of individual/small-group singing activities on kindergartners' use of singing voice and developmental music aptitude. *Journal of Research in Music Education, 44*(4), 353-368.

Sadakata, M., Hoppe, D., Brandmeyer, A., Timmers, R., & Desain, P. (2008). Real-time visual feedback for learning to perform short rhythms with expressive variations in timing and loudness. *Journal of New Music Research, 37*(3), 207-220.

Salmoni, A. W., Schmidt, R. A., & Walter, C. B. (1984). Knowledge of results and motor learning: a review and critical reappraisal. *Psychological bulletin, 95*(3), 355.

Savelsbergh, G. J. P., Kamper, W. J., Rabius, J., De Koning, J. J., & Schöllhorn, W. (2010). A new method to learn to start in speed skating: A differencial learning approach. *International Journal of Sport Psychology, 41*(4), 415.

Schankler, I., Smith, J., François, A., & Chew, E. (2011). *Emergent formal structures of factor oracle-driven musical improvisations*. Paper presented at the International Conference on Mathematics and Computation in Music, Paris, France.

Schelfhout, W., Dochy, F., & Janssens, S. (2004). The use of self, peer and teacher assessment as a feedback system in a learning environment aimed at fostering skills of cooperation in an entrepreneurial context. *Assessment & Evaluation in Higher Education, 29*(2), 177-201.

Schenk, T., Schindler, I., McIntosh, R. D., & Milner, A. D. (2005). The use of visual feedback is independent of visual awareness: evidence from visual extinction. *Experimental brain research, 167*(1), 95-102.

Schlaug, G., Norton, A., Overy, K., & Winner, E. (2005). Effects of music training on the child's brain and cognitive development. *Annals of the New York, NY Academy of Sciences, 1060*(1), 219-230.

Schleuter, S. L. (1972). An investigation of the interrelation of personality traits, musical aptitude and musical achievement. In E. Gordon (Ed.), *Experimental research in the psychology of music: Studies in the psychology of music*. Iowa City: University of Iowa Press.

Schmidt, C. P. (2006). Towards a Social-Psychological Model of Musical Ability. In K. Gfeller, D. D. Coffman, C. X. Rodriguez & D. J. Nelson (Eds.), *Multidisciplinary perspectives on musicality: Essays from the Seashore symposium*. Iowa City: School of Music, University of Iowa.

Schmidt, R. A. (1975). A schema theory of discrete motor skill learning. *Psychological review, 82*(4), 225.

Schmidt, R. A. (2008). Principles of practice for the development of skilled actions: Implications for training and instruction in music. In A. Mornell (Ed.), *Art in motion. Musical and athletic motor learning and performance* (pp. 41-67). Frankfurt am Main: Peter Langer.

Schmidt, R. A., & Wulf, G. (1997). Continuous concurrent feedback degrades skill learning: Implications for training and simulation. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 39*(4), 509-525.

Schmidt, R. A., Young, D. E., Swinnen, S., & Shapiro, D. C. (1989). Summary knowledge of results for skill acquisition: support for the guidance hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*(2), 352.

Schnabel, A., & Crankshaw, E. (1988). *My life and music*. Mineola, NY: Dover Publications.

Schnotz, W., & Lowe, R. (2003). External and Internal Representations in Multimedia Learning. *Learning and Instruction, 13*(2), 117-123.

Schöllhorn, W. (2000). Applications of systems dynamic principles to technique and strength training. *Acta Academiae Olympiquae Estoniae, 8*, 67-85.

Schoonderwaldt, E., & Wanderley, M. (2007). Visualization of bowing gestures for feedback: The Hodgson plot. Proceedings of the 3rd International Conference on Automated Production of Cross Media Content for Multi-channel Distribution (AXMEDIS07), vol. II, pp. 65–70, Barcelona, Spain.

Schoonderwaldt, E., Hansen, K., & Askenfeld, A. (2004). IMUTUS–an interactive system for learning to play a musical instrument. Paper presented at the International Conference of Interactive Computer Aided Learning, Villach, Austria.

Schubert, T., Friedmann, F., & Regenbrecht, H. (1999). Embodied presence in virtual environments, visual representations and interpretations. In R. Paton & I. Neilson (Eds.), Visual representations and interpretations (pp. 269-279). London: Springer Verlag.

Schunk, D. H. (1991). *Learning theories: An educational perspective*. New York, NY: Macmillan Publishing Company.

Schwarzer, R., Diehl, M., & Schmitz, G. (1999). Self-regulation scale. *Retrieved October, 28*, 2006.

Scruton, R. (1983). *The aesthetic understanding: Essays in the philosophy of art and culture*. London and New York, NY: Methuen.

Shea, C. H., & Wulf, G. (1999). Enhancing motor learning through external-focus instructions and feedback. Human Movement Science, 18(4), 553-571.

Sheets-Johnstone, M. (2010). Body and movement: Basic dynamic principles *Handbook of Phenomenology and Cognitive Science* (pp. 217-234).

Sheets-Johnstone, M. (2011). *The primacy of movement*. Amsterdam/Philadelphia: John Benjamins Publisher Company.

Shepherd, J. (2002). How Music Works. Beyond the Immanent and the Arbitrary An Essay Review of Music in Everyday Life. Action, Criticism, and Theory for Music Education, 1(2).

Shernoff, D. J., & Csikszentmihalyi, M. (2009). Cultivating engaged learners and pptimal learning environments. In R. Gilman, E. S. Huebner & M. Furlong (Eds.). Handbook of positive psychology in schools (pp. 131-145). New York, NY: Routledge.

Shernoff, D. J., Csikszentmihalyi, M., Schneider, B., & Shernoff, E. S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly, 18*(2), 158-176.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review, 57*(1), 1-23.

Slater, M. (1999). Measuring presence: A response to the Witmer and Singer presence questionnaire. Presence, 8(5), 560-565.

Sloboda, J. A. (2000). Individual differences in music performance. *Trends in Cognitive Sciences, 4*(10), 397-403.

Sloboda, J. A. (2001). Emotion, Functionality and the Everyday Experience of Music: where does music education fit? *Music Education Research, 3*(2), 243-253.

Sloboda, J. A., Davidson, J. W., Howe, M. J. A., & Moore, D. G. (1996). The role of practice in the development of performing musicians. *British Journal of Psychology, 87*(2), 287-309.

Smoliar, S. W., Waterworth, J. A., & Kellock, P. R. (1995). *pianoFORTE: a system for piano education beyond notation literacy.* Paper presented at the Proceedings of the third ACM international conference on Multimedia, New York, NY, USA.

Somekh, B. (2006). *Action Research: a methodology for change and development.* Maidenhead: Open University Press.

St John, P. A. (2006). Finding and making meaning: young children as musical collaborators. Psychology of Music, 34(2), 238.

Svinicki, M. D. (2008). Student learning: From teacher-directed to self-regulation. *New Directions for Teaching and Learning, 2010*(123), 73-83.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*(4), 295-312.

Sweller, J., Van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251-296.

Tai, T. C. (2010). *The effect of violin, keyboard, and singing instruction on the spatial ability and music aptitude of young children.* Doctoral dissertation, University of Maryland, Baltimore.

Takatalo, J. (2002). *Presence and flow in virtual environments: An explorative study.* Unpublished Master's thesis, University of Helsinki, Helsinki.

Takatalo, J., Häkkinen, J., Lehtonen, M., Kaistinen, J., & Nyman, G. (2002). Presence, involvement, and flow in digital games. Evaluating User Experience in Games, 24-48.

Tchernoff, E. (2007). Music Schools in Europe. A European study on the organisation of music schools and the preparation of students for professional music training at higher education level. Retrieved from www.musicschoolunion.eu

Teachout, D. J. (2001). The relationship between personality and the teaching effectiveness of music student teachers. *Psychology of Music, 29*(2), 179-192.

Teo, T. (2009). Modelling technology acceptance in education: A study of pre-service teachers. *Computers & Education, 52*(2), 302-312.
Thorpe, W. (2002). *Visual feedback of acoustic voice features in singing training.* Paper presented at the 9th Australian Speech Science & Technology Conference, Melbourne, Australia.
Todres, L. (2008). Being with that: The relevance of embodied understanding for practice. Qualitative health research, 18(11), 1566-1573.
Triantafyllaki, A. (2005). A call for more instrumental music teaching research. *Music Education Research, 7*(3), 383-387.
Trouche, L. (2004). Managing the complexity of human/machine interactions in computerized learning environments: Guiding students' command process through instrumental orchestrations. *International Journal of Computers for Mathematical Learning, 9*(3), 281-307.
Tsang, C. D., Friendly, R. H., & Trainor, L. J. (2011). Singing development as a sensorimotor interaction problem. *Psychomusicology: Music, Mind and Brain, 21*(1-2), 31.
Turner, P. (2008). Being-with: A study of familiarity. Interacting with Computers, 20(4-5), 447-454.
Upitis, R. (1999). Artistic approaches to research. *Music Education Research, 1*(2), 219-226.
Van Baren, J., & IJsselsteijn, W. (2004). Measuring presence: A guide to current measurement approaches. Deliverable 5 for OmniPres project
Van Der Linden, J., Johnson, R., Bird, J., Rogers, Y., & Schoonderwaldt, E. (2011). *Buzzing to play: lessons learned from an in the wild study of real-time vibrotactile feedback.* Paper presented at the International Conference on Human Factors in Computing Systems, CHI 2011, Vancouver BC, Canada.
Van Der Linden, J., Schoonderwaldt, E., Bird, J., & Johnson, R. (2011). Musicjacket: Combining motion capture and vibrotactile feedback to teach violin bowing. *IEEE Transactions on Instrumentation and Measurement, 60*(1), 104-113.
Van Merriënboer, J. J. G., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review, 17*(2), 147-177.
Van Petegem, P., & Vanhoof, J. (2002). Evaluatie op de testbank: een handboek voor het ontwikkelen van alternatieve evaluatievormen. Mechelen: Wolters Plantyn.
Van Regenmortel, H., & Strobbe, L. (2010). Klansporen. Breinvriendelijk musiceren. Antwerpen: Garant.
Vanderlinde, R., & Van Braak, J. (2010). The gap between educational research and practice: views of teachers, school leaders, intermediaries and researchers. *British Educational Research Journal, 36*(2), 299-316.
Vecchi, V. (2010). *Art and Creativity in Reggio Emilia: Exploring the role and potential of ateliers in early childhood education.* New York, NY: Taylor & Francis.
Velicer, W. F., & Fava, J. L. (1998). Effects of variable and subject sampling on factor pattern recovery. Psychological Methods, 3, 231-251.
Vérillon, P., & Andreucci, C. (2005). Artefacts and Cognitive Development: How do Psychogenetic Theories of Intelligence Help in Understanding the Influence of Technical Environments on the Development of Thought? In M. de Vries & I. Mottier (Eds.), *International Handbook of Technology Education: Reviewing the Past Twenty Years.* Rotterdam: Sense Publishers.
Vertegaal, R., Ungvary, T., & Kieslinger, M. (1996). Towards a musician's cockpit: Transducers, feedback and musical function. Paper presented at the International Computer Music Conference, Hong Kong

Vygotsky, L., Gauvain, M., & Cole, M. (1978). Interaction between learning and development. In M. Gauvain & M. Cole (Eds.), *Readings on the development of children* (pp. 34-41). Cambridge, MA: MIT press.

Wagman, J. B., & Carello, C. (2001). Affordances and inertial constraints on tool use. *Ecological Psychology, 13*(3), 173-195.

Waterworth, E. L., & Waterworth, J. A. (2001). Focus, locus, and sensus: The three dimensions of virtual experience. CyberPsychology & Behavior, 4(2), 203-213.

Watson, S. (2011). *Using Technology to Unlock Musical Creativity*. New York, NY: Oxford Univ Press.

Webster, J., Trevino, L. K., & Ryan, L. (1993). The dimensionality and correlates of flow in human-computer interactions. *Computers in Human Behavior, 9*(4), 411-426.

Webster, P. R. (2002). Computer-based technology and music teaching and learning. In R. Colwell & C. Richardson (Eds.). The New Handbook of Research on Music Teaching and Learning (pp. 416-439). Oxford: Oxford University Press.

Webster, P. R. (2007). Computer-based technology and music teaching and learning: 2000-2005. In L. Bresler (Ed.), International handbook of research in arts education (Vol. 2, pp. 1311-1330). Dordrecht: Springer.

Webster, P. R. (2011a). Construction of Music Learning. In R. Colwell & P. Webster (Eds.), *MENC Handbook of Research on Music Learning* (Vol. 1, pp. 35-83). New York, NY: Oxford University Press.

Webster, P. R. (2011b). Key research in music technology and music teaching and learning. *Journal of Music, Technology and Education, 4, 2*(3), 115-130.

Welch, G. (2009). Culture and gender in a cathedral music context: An activity theory exploration *A Cultural Psychology of Music Education*. New York, NY: Oxford University Press.

Welch, G. F. (2007). Addressing the multifaceted nature of music education: An activity theory research perspective. *Research Studies in Music Education, 28*(1), 23.

Welch, G. F. (2009). Ecological Validity and Impact: Key Challenges for Music Education Research. In: J. T. Gates & T. Regelksi (Eds.). Music Education for Changing Times: Guiding Visions for Practice. Landscapes: the Arts, Aesthetics, and Education (7), 149-159. Dordrecht: Springer

Welch, G. F., Himonides, E., Howard, D. M., & Brereton, J. (2004). *VOXed: Technology as a meaningful teaching aid in the singing studio.* Paper presented at the Conference on Interdisciplinary Musicology (CIM04), Graz, Austria.

Welch, G. F., Howard, D. M., Himonides, E., & Brereton, J. (2005). Real-time feedback in the singing studio: an innovatory action-research project using new voice technology. Music Education Research, 7(2), 225-249.

Widmayer, S. A. (2005). Schema theory: An introduction. *Retrieved April, 14.*

Wigfield, A., Tonks, S., & Klauda, S. L. (2009). Expectancy-value theory. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation at school* (pp. 55-75). New York, NY: Routledge.

Wilson, P. H., Lee, K., Callaghan, J., & Thorpe, C. W. (2008). Learning to sing in tune: Does real-time visual feedback help? *Journal of interdisciplinary music studies, 2*(1-2), 157-152.

Wilson, P. H., Thorpe, C. W., & Callaghan, J. (2005). *Looking at singing: does real-time visual feedback improve the way we learn to sing?* Paper presented at the Asia-Pacific Society for the Cognitive Science of Music, Seoel, South Korea.

Winstein, C. J., & Schmidt, R. A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(4), 677.

Witmer, B., & Singer, M. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence, 7(3), 225-240.

Witmer, B., Jerome, C., & Singer, M. (2005). The factor structure of the presence questionnaire. Presence: Teleoperators & Virtual Environments, 14(3), 298-312.

Woodside, A. G. (2004). Advancing from subjective to confirmatory personal introspection in consumer research. *Psychology and Marketing, 21*(12), 987-1010.

Woody, R. H. (2001). Learning From the Experts: Applying Research in Expert Performance To Music Education. Update: Applications of Research in Music Education, 19(2), 9-14.

Woody, R. H. (2004). Misconceptions about Scientific Research in Music Education. *Teaching Music, 11*, 6.

Woody, R. H. (2007). Popular music in school: Remixing the issues. *Music Educators Journal, 93*(4), 32-37.

Woszczynski, A. B., Roth, P. L., & Segars, A. H. (2002). Exploring the theoretical foundations of playfulness in computer interactions. Computers in Human Behavior, 18(4), 369-388.

Woszczynski, A., Roth, P., & Segars, A. (2002). Exploring the theoretical foundations of playfulness in computer interactions. *Computers in Human Behavior, 18*(4), 369-388.

Wulf, G., & Lewthwaite, R. (2009). Attentional and motivational influences on motor performance and learning. In A. Mornell (Ed.), *Art in Motion: Musical and Athletic Motor Learning and Performance* (pp. 95-117). Frankfurt am Main: Peter Lang.

Wulf, G., McConnel, N., Gärtner, M., & Schwarz, A. (2002). Enhancing the learning of sport skills through external-focus feedback. *Journal of motor behavior, 34*(2), 171-182.

Wulf, G., Shea, C. H., & Matschiner, S. (1998). Frequent feedback enhances complex motor skill learning. *Journal of Motor Behavior*, 30(2), 180-192.

Yarbrough, C., Price, H. E., & Hendel, C. (1994). The effect of sequential patterns and modes of presentation on the evaluation of music teaching. *Bulletin of the council for research in music education, 120*, 33-45.

Yin, J., Wang, Y., & Hsu, D. (2005). *Digital violin tutor: an integrated system for beginning violin learners.* Paper presented at the 13th ACM International Conference on Multimedia, Singapore.

Young, V., Burwell, K., & Pickup, D. (2003). Areas of Study and Teaching Strategies Instrumental Teaching: a case study research project. *Music Education Research, 5*(2), 139-155.

Yu, P. T., Lai, Y. S., Tsai, H. H., & Chang, Y. H. Using a Multimodal Learning System to Support Music Instruction. Educational Technology & Society, 13(3), 151-162.

Zahorik, P., & Jenison, R. L. (1998). Presence as being-in-the-world. Presence, 7(1), 78-89.

Zanolla, S., Roda, A., Romano, F., Scattolin, F., Foresti, G. L., & Canazza, S. (2011). *When sound teaches.* Paper presented at the Sound and Music Computing Conference, Padova, Italy.

Zatorre, R., Chen, J., & Penhune, V. (2007). When the brain plays music: auditory-motor interactions in music perception and production. *Nature Reviews Neuroscience, 8*(7), 547-558.

Zdzinski, S. F. (1992). Relationships among parental involvement, music aptitude, and musical achievement of instrumental music students. *Journal of Research in Music Education, 40*(2), 114-125.

Zhukov, K. (2004). *Teaching styles and student behaviour in instrumental music lessons in Australian conservatoriums.* Doctoral dissertation, University of New South Wales (Australia).

Zinchenko, V. (1996). *Developing activity theory: The zone of proximal development and beyond*. Cambridge, MA: MIT Press.